13th ISCAR National Symposium

Fostering Resilient Coastal Agro-Ecosystems

Souvenir

22nd - 25th February, 2023

ANGRAU, RARS, Tirupati, Andhra Pradesh

Organized by

ISCAR

Indian Society of Coastal Agricultural Research
Canning Town, West Bengal

ANGRAU

Acharya N.G. Ranga Agricultural University
Lam, Guntur, Andhra Pradesh

ICAR-Central Soil Salinity Research Institute
Karnal, Haryana

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Edited and Compiled by
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Email : vsmartcentre@gmial.com
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KAKANI GOVARDHAN REDDY
B.E., M.B.A., M.A.,
Minister for Agriculture, Cooperation,
Marketing & Food Processing,
Government of Andhra Pradesh

MESSAGE

Coastal areas provide excellent soil and climatic conditions for agriculture and often play an important role in the economy, with food and raw material for industry. Agriculture is the major occupation of the people in the rural areas of coastal regions of the country, but it is highly complex, risk-prone and entirely dependent on the vagaries of nature. Climatic and non-climatic stressors, such as high temperatures, rainfall fluctuations, population growth and migration, pollution, land-use changes and inadequate gender-specific strategies, are major challenges to coastal agricultural sustainability.

Integrated farming system through land shaping models needs to be outsealed in different coastal regions of the country for sustainable use of natural resources for higher crop diversification, improving livelihoods of farmers and to accelerate the agricultural production and growth. Further, there are opportunities for intensification of agriculture and allied enterprises through efficient use and optimal management of fresh surface and groundwater resources, careful planning of the crop calendar and efficient agronomic practices that maximize resource use efficiency. Hence, regular monitoring of the coastal zone is indispensable for preparation of suitable coastal zone management plan, as well as, in implementation of regulations in the coastal zone.

The 13th National Symposium on 'Fostering Resilient Coastal Agro-Ecosystems' being organized from 22nd to 25th February. 2023 by The Indian Society of Coastal Agricultural Research, (ISCAR), Canning Town, West Bengal in collaboration with ANGRAU. Lam. Guntur and ICAR-Central Soil Salinity Research Institute, Kamal. Haryana may be fruitful and serve as an effective platform for studying and analyzing the challenges faced by the coastal farming community and come out with strategies for integrated coastal resource management, crop diversification and formation of suitable policies to accelerate the agricultural production, marketing and enhance their livelihood.

I wish the National Symposium to be successful in all the ways.

(KAKANI GOVARDHAN REDDY)

Dr. APPALARAJU SEEDIRI
MD, (Gen. Med.)
Minister for Animal Husbandry,
Dairy Development & Fisheries,
Government of Andhra Pradesh

MESSAGE

It is noted that in India, the coastal ecosystem covers an area of 10.78 million ha along 9000 km long coastline. By and large, rice is the staple food in the coastal region besides other food resources like fish, meat, milk and milk products and regional vegetable and fruits. The coastal ecosystem possesses 19.5% of the livestock population of total Indian livestock. A total of 35 well recognized (registered with National Bureau of Animal Genetic Resources, Kamal) livestock and poultry breeds are available from this region. Animal husbandry in coastal region has a major role in agricultural community activities and provides considerable income for these small and marginal farmers' families. Enhancement of income for farmers through livestock- crop integration makes system sustainable. The vast population and diversity of livestock in the coastal India could prove to be a vital asset for the country and a sustainable livestock production system will continue to propel coastal agriculture through sound integration. It also has a vibrant fishery sector and the water bodies in the coastal line present opportunities for exploiting both inland and marine fisheries.

In the livestock sector, focal areas of attention include breeding of cattle and other meat animals, improvement of local breeds of cattle, scientific rearing of rabbits and goats, backyard poultry rearing, nutrition and health care. There are many issues related to coastal agriculture that need to be addressed including development of integrated farming system models for effective utilization of available homestead resources and holistic watershed development, diversification through development of agro-eco tourism, effective utilization of fallow lands for profitable production of field and horticultural crops, livestock rearing, diversification in brackish water aquaculture and secondary agriculture. Particularly with the development of suitable integrated farming system models so that farmers of coastal rural areas may be shifted to other allied enterprises with livestock, poultry and fisheries and is to be encouraged with suitable frame work and fruitful policies to provide better alternative income.

At this juncture,, I am happy to hear that The Indian Society of Coastal Agricultural Research, (ISCAR), Canning Town, West Bengal in collaboration with ANGRAU, Lam, Guntur and ICAR-Central Soil Salinity Research Institute, Kamal, Haryana is organizing the 13th National symposium on 'Fostering Resilient Coastal Agro-Ecosystems from 22nd to 25th February, 2023' at RARS, Tirupati and trust it could bring a roadmap for planning effective strategic research programmes those are needed to withstand the onslaught of natural calamities and mitigate their impact on farming sector.

I Wish the National symposium a grand success.

(APPALARAJU SEEDIRI)

Dr. A. VISHNUVARDHAN REDDY
Vice Chancellor
Acharya N.G. Ranga Agril. University
Lam, Guntur

MESSAGE

About one fourth of Indian population depends on coastal environment, which occupies around 5.5 per cent of the total land area of the country. Coastal ecosystem, despite of being potentially rich in natural resources with ecological, economical and social significance, it has to withstand the onslaught of various natural calamities including increase in temperature, changing patterns of rainfall, tropical cyclones and extreme events, as well as sea-level rise, floods and coastal inundation which in turn greatly influence the activities of agriculture and allied sectors.

The ICAR-Central Coastal Agricultural Research Institute (CCARI) had launched a Coastal Agricultural Information System (CAIS) in 2022 for the benefit of farmers, scientists and policy makers, which acts as a knowledge platform and a way forward to sustainable coastal agriculture. It is viewed that there are immense opportunities for enhancing the productivity of coastal lands through efficient management of fresh surface and groundwater resources, rainwater harvesting, varietal improvement of crops, careful planning of the crop calendar, better crop management practices, integrated cultivation of agriculture-horticulture-social forestry (with mangrove and non-mangrove plants) crops along with pisciculture-livestock- poultry etc. Planning and execution of the appropriate research and transfer of technology programmes are needed to be taken up to harness the power of science in increasing productivity and profitability, enhancing resource use efficiency, developing suitable models of integrated farming systems, agro-eco-tourism, reducing cost and post-harvest losses, improving livestock productivity and diversification of brackish water aquaculture and ornamental fish culture and along with linking of farm to markets are the need of the hour.

At this juncture, on behalf of ANGRAU I feel delighted to collaborate with The Indian Society of Coastal Agricultural Research, (ISCAR), Canning Town, West Bengal and ICAR-Central Soil Salinity Research Institute, Karnal, Haryana in organizing 13^{th} National symposium on 'Fostering Resilient Coastal Agro-Ecosystems' to be conducted from 22^{nd} to 25^{th} February, 2023 at RARS, Tirupati. Further I look forward that National symposium outlines a roadmap for multipronged disciplinary approach and to foster linkages and collaborations with public and private, national and international organizations for future strategic plan of work.

I wish the National Symposium a grand success...

(A. VISHNUVARDHAN REDDY)

Prof. V. PADMANABHA REDDY
Vice Chancellor
Sri Venkateswara Veterinary University
Tirupati

MESSAGE

include two islands under Indian Territory. India has diverse coastal features along its vast coastline of 7515.6 km, consisting of mangroves, coral reefs, sea grass meadows, and salt marshes. Coastal communities are largely dependent for their livelihood on fisheries, forestry, animal husbandry and tourism. Livestock are an integral component of agriculture in India and make multifaceted contributions to the growth and development of the agricultural sector which includes animal husbandry, dairy and fisheries sector plays a significant role in the national economy and in the socio-economic development of the nation. Livestock help improve food and nutritional security by providing nutrient-rich food products, generate income and employment and act as a cushion against crop failure, provide draught power and manure inputs to the crop subsector, and contribute to foreign exchange through exports. The Gross Value Added (GVA) from livestock products across Andhra Pradesh was seen steadily increasing over years and reached to around 750 billion INR.

Despite positive growth in livestock population and production, the development of livestock sector is hampered by several factors that need immediate attention and interventions in areas of research, extension, administration, and policies of state and central governments should intensify the facilities for processing and value addition of livestock produce, availability of credit to livestock sector, create more access to markets, establish organized market linkages for the overall development of livestock sector in the state.

I believe that the present national symposium will be instrumental through wide deliberations among the scientists, policy makers, NGO's and progressive farmers for sustainable development of livestock sector by addressing the key issues being faced by the farming community especially in coastal area.

I wish the 13th ISCAR National Symposium a grand success.

(V. PADMANABHA REDDY)

Dr. T. JANAKIRAM
Vice Chancellor
Dr. Y.S.R. Horticultural University
Venkataramannagudem

MESSAGE

It gives me immense pleasure to know that Regional Agricultural Research Station, Acharya NG Ranga Agricultural University, Tirupati, Andhra Pradesh in collaboration with Indian Society of Coastal Agricultural Research (ISCAR), Canning Town, West Bengal, India is organizing the 13th National symposium on **"Fostering Resilient Coastal Agro-Ecosystems"** at RARS, Tirupati during February, 22-25, 2023.

The people in the coastal agriculture system suffer significant micronutrient and protein deficiencies because of imbalanced dietary habits. Despite many constraints and adversities in coastal areas, there lies a tremendous scope for enhancing agriculture productivity through development and adoption of location and problem- specific technologies and strategies in the field of natural disaster management, soil health management, water management, crop management etc. Rice is the staple food of coastal inhabitants of India, and rice based mono cropping is the major cropping system followed in these belts. Crop diversification with horticultural crops offers great scope for sustainability and nutritional security since the horticultural crops with nutraceutical properties are often considered as protective foods.

Horticultural crops provide a viable option for ensuring the livelihood security of coastal farmers. The economic returns per unit area are high in horticultural crops when compared to field crops. The coastal zones of India are in great need of taking up the horticulture as one of the integral components of the coastal agriculture system on large scale. Horticulture with diverse group of crops offers a range of crop choices to the farmers for crop diversification in coastal agriculture. Availability of moisture throughout the year with excellent soil and climatic conditions facilitates cultivation of horticultural crops. Salt-affected soils of coastal land could be utilized for the cultivation of coconut, date palm, ber, sapota, aonla, karonda, and custard apple because of moderate to high salt tolerance ability.

I personally believe that the deliberations of the proposed National seminar involving subject matter experts, intellectuals, scientists, policy makers and the stake holders from the coastal sector in the country would definitely pave a way to enhance the profitability to the coastal farmers and also to bring self sufficiency in the coastal ecosystems in the near future.

I wish the National Seminar a grand success.

(T. JANAKIRAM)

Dr. L. PRASANTHI
Director of Research
Acharya N.G. Ranga Agril. University
Lam, Guntur

MESSAGE

The coastal region of India is known for its rich diversity of climate, topography, soils, crops, livestock, fisheries, etc. Despite the abundance of natural resources, the productivity of crops and livestock in this region is poor as compared to the inland regions. Unlike the other parts of the country, the region faces unique problems like demographic pressure, land degradation, rapid urbanization, industrialization, environmental pollution, and climate change effects like increased frequency of floods, droughts, cyclones, and sea level rises. Gujarat rank first, in terms of coastal line, with extensive coastline extending 1214.7 km adjacent to the Arabean sea, accounting around 23% of total mainland coastline of the country. Andhra Pradesh is in second position with coastline length of 974 km extending between Ichapuram of Srikakulam districts to Tada of Nellore district. The third biggest mainland coastal line stretches up to 906.9 km in Tamil Nadu. The majority of nations with sizable coastal ecosystems are threatened by extreme weather and climate change. Therefore, appropriate measures must be adopted, especially in developing nations, to lessen the vulnerability of farming communities in coastal areas.

The smallholder production systems that dominate the coastal zone produce considerable food supplies. Paddy lands (e.g. acid-saline soils and the unique social- ecological systems of South Western India and elsewhere), rice and fish/shrimp farming systems, coconut-based mixed farming systems, spice crops, and the time-tested agro forestry practices are among the major coastal land-use systems that contribute significantly to food and nutritional security. To meet the rising food demand while also conserving coastal ecosystems in a changing climate, win-win strategies for ecosystem services and climate resilience are required. Integrated coastal zone management is critical for ensuring food security for the coastal population. Environment friendly farming practices such as agro forestry and tree based farming, which increase carbon stocks in the soil and biomass, as well as low-impact restorative aquaculture practices, are critical for sustaining the ecological integrity of these fragile ecosystems. Resource inventories for coastal districts must be developed as a way forward. Fine-tuning farming system options for best land and water utilization and optimizing returns are to be suggested.

It is privilege to organize the 13th National Symposium on 'Fostering Resilient Coastal Agro-Ecosystems' from 22nd to 25th February, 2023 at ANGRAU, RARS, Tirupati by The Indian Society of Coastal Agricultural Research, (ISCAR), Canning Town, West Bengal and ICAR-Central Soil Salinity Research Institute, Kamal, Haryana. Symposium I wish the symposium will definitely be fruitful and come up with a road map for sustainable coastal agro ecosystems. I congratulate the whole team of organizers of this national symposium.

L. Prasanthi

(L. PRASANTHI)

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The financial assistance received from the Research and Development Fund of National Bank for Agriculture and Rural Development (NABARD) towards the printing of proceedings of the symposium is gratefully acknowledged. The society would also like to put on record the painstaking efforts taken by the staff of ANGRAU, RARS, Lam, Guntur and Regional Research Station, Canning Town, West Bengal, India in organizing the event successfully.

Organizers

CONTENTS

Coastal and Marine Ecosystem Services in India

Uttam Kumar Mandal[1], Richen Nopu Bhutia[1], T.D. Lama[1], Dhiman Burman[1], Amit Ghosh[1], Dibyendu Bikas Nayak[1], Sudipa Mal[1], Subhasis Mandal[2], K.K. Mahanta[1], Nitish Ranjan Prakash[1], Shishir Raut[1] and S.K. Sarangi[1]

[1] ICAR-CSSRI, RRS, Canning Town, West Bengal-743 329, India
[2] ICAR-CSSRI, Karnal, Haryana, RRS, Canning Town, West Bengal-743 329, India
Corresponding author: uttam_icar@yahoo.com

The global coastline is about 440,000 km long (Ouillon, 2018) and varies greatly around the world from frozen polar shorelines to tropical mangroves and beaches. Coastal regions include coastal seas on the continental shelf to a depth of 50 m, the coastline and the adjacent land that is routinely inundated with seawater and extend over approximately 2.3-7.0 million km^2 (Duarte *et al.,* 2013). In general, the coastal and marine environment can extend up to 100 km inland and up to 50 m water depth in the ocean (Mehvar *et al*., 2018). Coastal and marine wetlands include estuaries, lagoons, barrier islands, coastal peat lands, swamps and beaches. Tropical and subtropical coastlines are dominated by mangroves, sandy beaches, coral reefs, and seagrass beds, whereas tidal marshes, macro algal forests, and seagrass beds abound on higher latitude coast lines. While coastal areas cover only 4% of the earth’s total land area and are equivalent to only 11% of the World’s ocean area, they host one third of the World’s population and are twice as densely populated as inland areas (Barbier, 2013; Mehvar *et al*., 2018).

In India around 250 million populations reside within 50 km of the 7500 km coastline that is shared by 9 states and 2 union territories comprising 77 towns and cities including 3 megacities *viz.*, Mumbai, Kolkata and Chennai. The coastline supports several economic activities that are vital for India’s economy like oil and gas, ports and harbors, power plants, fishing, tourism and mining that keep affecting the coastal ecology and environment (Mandal *et al*., 2021). Same time it is important to note that Indian coastal stretches are well endowed with highly productive ecosystems that support coastal human population in numerous ways, ranging from alleviating their poverty by offering variety of coastal resources, to protecting them from natural and man made hazards like erosion, cyclones, storm surges, tsunamis, pollution etc. The total value of coastal and marine ecosystem services in India is estimated to approximately Rs. 1.5 trillion, of which provisioning services (food, water, timber and fibre) account for 26 per cent, regulating services (coastal protection, carbon sequestration, waste recycling, water purification and erosion control) account for 44 per cent and coastal recreation (recreational, aesthetic and spiritual fulfillment, and education) accounts for 30 per cent of the total value which is approximately 3.2 per cent of Net National Product (NNP) in 2012-13 (Kavi Kumar *et al*., 2016). Healthy coastal ecosystems are also considered as an effective and inexpensive defense against coastal hazards, besides being helpful in offering multiple options of livelihood for the coastal population.

Despite the multitude of services that coastal ecosystems provide us, however, their degradation and the subsequent loss of biodiversity continues at an unprecedented rate. This undermines coastal ecosystem functioning and resilience and thus threatens the ability of coastal ecosystems to continuously supply the flow of services for present and future generations. These threats are expected to increase as a result of climate change and a growing world population that has increasing consumption needs.

They can, therefore, no longer be considered as inexhaustible resources. An estimated 340,000 ha to 980,000 ha of coastal ecosystems are being destroyed globally each year. As much as 67%, and at least 35% and 29% of the global coverage of mangroves, tidal marshes and seagrass meadows respectively have been lost (The Blue Carbon Initiative, 2020). If these trends continue, with business as usual, an additional 30% to 40% of tidal marshes and seagrasses and nearly all unprotected mangroves could be lost in next 100 year (The Blue Carbon Initiative, 2020). Rather than sink of atmospheric CO_2, degraded and depleted coastal ecosystems can become source of greenhouse gases (e.g., CO_2, CH_4 and N_2O) (Lal, 2022).

Vegetated Coastal habitats in the biosphere

Characterized by the presence of macrophytes, both submerged (seagrass and macro algae) and partially emerged (mangroves and salt marshes), these habitats occupy from the intertidal zone to about 40 m depth in sea along the shores of all continents, with macro algae being the largest contributors and mangroves accounting for the smallest area (Duarte *et al.*, 2013) (Table 1). Salt marshes, mangroves, seagrass meadows, Kelp forest and coral reefs are occupying the major coastal habitats in the biosphere. Salt marshes are intertidal halophytic herbaceous rooted vegetation particularly prevalent in temperate and arctic latitudes from 30° to 80° and are usually restricted to comparatively sheltered locations. Salt marshes are estimated to cover roughly 54,951 km^2 worldwide (Mcowen *et al*., 2017), mostly found outside the tropics, especially in the low-lying, ice-free coasts, bays and estuaries of the North America and Canada (41%), followed by Oceania (24%), Russian Federation (13%), China (10) and Europe (8%) (Mcowen *et al.*, 2017).

Table 1. Extension, production, carbon burial and soil stocks of vegetate coastal ecosystems (Duarte *et al.*, 2013, 2016)

Ecosystem	Global Extension (km^2)	Local net primary production (g C m^{-2} yr^{-1})	Global net primary production (Pg C yr^{-1})	Local C burial rate (g C m^{-2} yr^{-1})	Local C stock in soil (Mg C ha^{-1})	Global C burial rate (Tg C yr^{-1})	Global C stock in soil (Pg C)
Salt Marshes	22000-400000	1100	0.02-0.44	218±24	162	4.8-87.3	0.4-6.5
Mangroves	137760-152361	1000	0.14-0.15	163	255	22.5-24.9	9.4-10.4
Seagrasses	177000-600000	817	0.14-0.49	138±38	139-7	48.0-112	4.2-8.4
Macro algae	2000000-6800000	750	2.55				

In India salt marshes are distributed in seven coastal districts/UTs, viz. Gujarat, Daman and Diu, Maharashtra, Tamil Nadu, Puducherry, Andhra Pradesh and Andaman & Nicobar Islands, covering an approximate area of 1600 km^2. Gujarat has the highest area cover of 89.5% of total cover, followed by Tamil Nadu (3.8%), Andaman & Nicobar Islands (3.7%), Andhra Pradesh (2.5%), Maharashtra (0.4%), Puducherry (0.04%) and Daman and Diu (0.04%) (Banerjee *et al*., 2017).

Mangroves are diverse assemblages of trees, shrubs, palms, and ferns that are adapted to the intertidal zone of flat, sheltered coastlines in the tropics and subtropics. They produce pneumatophores or air roots up from the mud. They can also produce roots that go downwards into the water. They are viviparous- the seeds germinate in the tree itself. Global mangrove area is estimated at 152 000–160 000 km^2, with 43% found in Indonesia, Australia, Brazil, and Nigeria (Heckbert *et al*., 2012). According to the recent Indian State of Forest Report 2019, the current area under mangroves in India is 4,975 sq km, where Sundarbans in West Bengal occupies 42.5% and Gujarat, Andaman and Nicobar Islands, Andhra Pradesh, Odisha and Maharashtra covers 23.7%, 12.4%, 8%, 5%, 6.4% mangrove area, respectively (MOEF, 2019).

Mangroves provide a wide range of ecosystem services and are particularly important for communities in developing, tropical nations with subsistence economies. Mangroves are highly productive systems and extremely efficient carbon sinks. On an areal basis, mangroves are generally more productive than salt marshes and seagrasses. Productivity is higher in the tropics than in the subtropics, with a decline in aboveground biomass with increasing latitude. Mangroves are heavily used traditionally, as sources of wood for building materials and for food provision in terms of gathering and cultivation of shellfish, fish, and crustaceans, and commercially for wood products (Alongi, 2002). The greatest threats to mangroves are deforestation, overexploitation of wood and fisheries resources, and pond aquaculture, particularly prawn aquaculture, which requires clearing of mangroves, alters groundwater tables, and releases toxic wastes (Alongi, 2002; Heckbert *et al.,* 2012). Mangroves are highly sensitive to changes in soil salinity and humidity; hence, rainfall patterns are a key regulating factor. Mangroves are extremely sensitive to impacts of climate change, particularly rising sea level and alteration of rainfall. Globally, up to 35% of the mangrove area has been lost since the 1980s, primarily due to different coastal development activities as well as climate change impact (Curnick *et al*., 2019).

The Sundarbans, the largest contiguous mangrove ecosystems is located in the delta formed by confluence of the Ganges, Brahmaputra and Meghna rivers in Bay of Bengal situated within West Bengal, India and Bangladesh. A large area of Indian Sundarbans is protected by the Sundarban Biosphere Reserve (SBR); however, isolated mangrove forests distributed among various islands in the SBR suffer from continuous degradation. The river shorelines in the Indian Sundarbans that are typically fringed by mangroves are extremely vulnerable to anthropogenic stresses, such as deforestation, dredging, infrastructure development catering to tourism, reconstruction of sea dykes and embankments through the use of dredged sand and mud from river shoreline and mudflat zones, prawn larvae catching, and fish farming along the shoreline. Apart from anthropogenic stressors, natural stressors (e.g., frequent cyclonic storms, increased salinity, sea level rise, and shoreline erosion) also pose major threats by causing the decline of mangrove fringes in Indian Sundarbans.

The recent two consecutive cyclones Amphan in 2020 and Yaas 2021 causes considerable damage to Sundarban’s mangrove which otherwise is used to form the first line of defense, may help in reducing the impact of the waves that are triggered during cyclones, thus protecting the embankments as well as nearby villages and towns. West Bengal planted 50 million mangrove saplings after cyclone Amphan and planned to plant 150 million mangrove saplings in to protect the coast from cyclones (Hindustan Times, June 08, 2021). There are certain deep rooted mangrove species such as Rhizophora, Bruguiera and Avicennia which may not only act as a bio-shield, but if planted on the embankments, may also help to bind the soil and make them more robust.

Seagrasses are marine flowering plants found in intertidal and shallow waters along the coastlines. They can form extensive meadows, with temperate meadows tending to be dominated by one or two larger species and tropical meadows having a greater diversity of plants. Seagrass global extent is estimated at 0.3 million km^2 (Kennedy and Bjork, 2009), but this is likely to be grossly underestimated as inventories have not been carried out or are incomplete for many countries.

Seagrasses tend to have an extensive underground system of roots and rhizomes (horizontal underground stems that can form extensive networks) and spread through vegetative budding of rhizomes as well as by flowering and seed production. Larger species such as *Posidonia oceanica*, which is endemic to the Mediterranean Sea, have large rhizomes and can raise the seafloor by several meters over thousands of years (Heckbert *et al.*, 2012). More than a third of the primary production (rhizomes and leaf sheaths) may be stored in the matte and organic carbon content can be as high as 40% where decomposition rates are slow. Seagrasses are important carbon sinks, and long-term carbon sequestration rates (Gg-C yr^{-1}) globally. Seagrass carbon burial rates are about half as fast on a per area basis as mangroves and salt marshes (Duarte *et al.*, 2013). Seagrass meadows can form long-term carbon sinks because much of their biomass (15–50%) is below ground, depending on the species.

Seaweed is another marine eukaryotic photosynthetic organisms belongs to the kingdom Protista. It is an algae and unlike seagrass it lacks true stem, roots, leaves and vascular tissues. There are essentially three primary types of seaweed - red (Rhodophyta), green (Chlorophyta), and brown (Ochrophyta) varying in colours and pigmentation. For the purpose of commercial use, it is usually collected by fishing communities and then further processed to obtain by-products which are then used in different industries. In India, the cultivation of seaweeds is undertaken along the Gulf of Mannar and Palk Bay in Tamil Nadu, Gujarat, Andaman-Nicobar islands and in other coastal regions of the country (Kavi Kumar *et al.*, 2016). Natural seaweeds occur mainly in Tamil Nadu, Odisha and Gujarat.

In India, CSIR (Council of Scientific and Industrial Research), CSMCRI (Central Salt and Marine Chemicals Research Institute) and ICAR (Indian Council for Agricultural Research) are creating awareness and promoting the cultivation of seaweed due its commercial potential as a natural resource. Seaweed can be consumed as edible food. It is also a source of fish/animal feed. It is further processed and used in the pharmaceutical, food and cosmetic industry. It is also used as a raw material for biofuels, fertilizers and soil conditioners. Thus, seaweed is an important resource provided by the sea that needs to be valued.

Kelps forests are large, brown algae found along rocky intertidal and shallow coastal areas globally. They dominate autotrophic biomass in temperate and Arctic regions, where they form extensive stands or forests (Heckbert *et al*., 2012). Giant canopy-forming kelp, Macrocyctis spp., can grow to 45 m long within a couple of years. A total of 58 774 km of coastline globally is believed to support kelp, although a complete world survey has not been conducted. Little is known of tropical kelps, but deepwater kelp forests do occur in the tropics, where cool oceanic currents and upwelling exist below uninhabitable warm surface waters. These tropical kelp forests are estimated to cover 23504 km^2. The most conspicuous kelps are the giant kelps Laminaria, Ecklonia, and Macrocyctis. They are found along temperate, nutrient-rich coastlines where they are foundation ecosystem species supporting a wide variety of plants and animals, including commercial species of fish, lobster, abalone, and urchins. Unlike salt-marsh plants, mangroves, and seagrasses, kelp species have no below ground biomass, as kelp plants are anchored to the surface of hard substrate by holdfasts. Carbon cycling in kelp is characterized by rapid biomass turnover and kelp detritus is consumed, decomposed, or exported out of the system. As growth depends on interactions among temperature, nutrient availability, and light, kelp forests are threatened by declining water quality and climate change.

Coral reefs are complex structures made from calcium carbonate secreted by colonies of small cnidarians known as polyps. Coral reefs are distributed in warm, shallow tropical and subtropical seas covering some 600000 km^2 (Smith and Gattuso, 2009). Services provided by coral reefs are critical for the livelihoods of millions of people and include fisheries, coastal protection, building materials, new biochemical compounds, and tourism. Most of the carbon (∼95%) sequestered by coral reefs is inorganic carbon in reef calcification (Smith and Gattuso, 2009). They are rapid producers of organic carbon and skeletal calcium carbonate. Coral reef systems, thus, do not have the potential to play a significant role in the long-term management of GHGs as in other coastal habitats (Smith and Gattuso, 2009). A total of 19% of coral reefs have been lost over the past 60 years, while 20% are under threat of loss over the next 20–40 years. Much of this is because of eutrophication and removal of grazing fish, but sea surface temperature rise and ocean acidification are considered as increasingly important threats to the biological performance and survival of corals and calcareous algae.

Ecosystem services provided by coastal habitat

Marine and coastal ecosystems provide a wide range of services to human society including supporting, regulating, cultural and provisioning services. These services influence human welfare both directly, through human use, and indirectly, via impacts on supporting and regulating services in other environments. The goods from estuarine and coastal ecosystems (ECE) include food for humans and animals (including fish, shellfish, krill, and seaweed); salt; minerals and oil resources; construction materials (sand, rock, coral, lime, and wood); and biodiversity, including the genetic stock that has potential for various biotechnology and medicinal applications (Heckbert *et al*., 2012).

Carbon sequestration

Marine and coastal ecosystems provide an important function of capturing and storing carbon, which is currently referred to as “blue carbon” to distinguish it from terrestrial sinks of carbon. Carbon that is “biologically fixed” by marine vegetation and microorganisms, and sequestered by burial in sediments, is secured for millennia if left undisturbed. Despite their global land cover (~0.5% of the sea bed) they sequester and store just as much as their terrestrial counterparts. Mangroves, salt marshes, seagrass meadows, macroalgal forests, and coastal shelves sequester carbon from the atmosphere and, in some cases, from dissolved aquatic CO_2. The large carbon sink capacity of Ecosystem and coastal ecosystems (ECEs) is a consequence of their slow decomposition rates in anaerobic conditions, which build organic soil stocks. ECEs also trap large quantities of sediments from anthropogenic and natural water sources. It has been estimated that detritus burial from vegetated coastal habitats contributes about half of the total carbon burial in the ocean (Duarte *et al.,* 2013). Each unit of carbon sequestered in mangroves, salt marshes, and sea-grasses is considered to be of greater value than that stored in any other natural ecosystem due to the lack of production of other GHGs, as tidal wetlands produce little methane gas compared to freshwater wetlands, which emit a large fraction of the annual global flux of methane (Heckbert *et al*., 2012).Despite the small fraction of the ocean surface occupied by saltmarsh, mangrove and seagrass ecosystems, they account for 46.9% of the total carbon burial in ocean sediments. Most macroalgal stands develop on hard, rocky substrates, and — despite their high productivity (Table 1) and capacity to trap suspended particles — do not develop significant carbon deposits. Community primary production generally exceeds respiration in vegetated coastal habitats leading to their capacity for producing excess organic carbon and acting as CO_2 sinks (Duerte *et al.,* 2013). Carbon sequestration in vegetated coastal habitats is further enhanced by their unique ability to trap particles from the water flow and store them in the soil.

As a result, burial rates of organic carbon in salt marsh, mangrove and seagrass ecosystems are exceptionally high (Table 1), exceeding those in the soils of terrestrial forests by 30–50 fold (Mc Leod *et al.*, 2011). The carbon buried in coastal vegetated ecosystems can be preserved over millennia, as demonstrated by radio carbon dating of seagrass, salt marsh and mangrove. The efficient preservation of the carbon under these habitats is due to: slow decomposition rates; low nitrogen and phosphorous concentrations in plant tissues; low oxygen levels in the sediments; and the allocation of a large fraction, often exceeding 50%, of plant biomass production to roots and rhizomes that are buried into the soil. In addition, the entangled network of roots (and rhizomes) and the dense canopy of coastal vegetation protect soil carbon deposits from erosion.

Indeed, some vegetated coastal habitats can support organic-rich soils that deserve conservation measures. Seagrass, salt marshes and mangroves accumulate enough carbon and mineral particles to support characteristic sediment accretion rates exceeding 10 cm per century, with the highest accretion rates found in salt marshes (Duarte *et al*., 2013). Accretion rates in mangrove forests have been reported to average 28 cm per century (Duarte *et al*., 2013). Moreover, sediment accretion responds to climate change through feedbacks that involve increased plant growth and production, which are conducive to faster accretion rates with increasing CO_2 and sea-level rise. Indeed, recent models indicate that climate change will increase salt marsh carbon burial and accretion rates in the first half of the twenty-first century. Globally, salt marsh, mangrove and seagrass ecosystems store about 10 Pg C each in their top 1-m soil layer.

Mangroves are considered one of the most carbon rich forests in the Indo-Pacific region. High levels of below-ground biomass (intricate and extensive root systems) and considerable storage capacity of organic carbon in mangrove sediment soils are the main reasons for their high carbon sequestration rates. For instance, mangrove forests sequester 6 times greater carbon per year than north-eastern tropical semi-evergreen forests and tropical dry deciduous forests and 10 times more than tropical thorn deciduous forests. These numbers should potentially provide sufficient incentive to encourage positive conservation and rehabilitation programmes for mangrove forests in the country.

Among coastal and marine ecosystems, seagrass meadows are one of nature’s most effective ecosystems for sequestering (capturing and storing) carbon. Therefore, if the same are sustainably managed, they can contribute enormously to reducing the adverse impacts of climate change. Globally, seagrass meadows occupy less than 0.2 per cent of the ocean floor but the proportion of carbon buried annually exceeds 10 per cent. The sediments of seagrass meadows are known to have extremely high saturation levels and their rates of carbon sequestration are over 30 times than that of tropical rainforests (Heckbert *et al*., 2012). Apart from sequestering and storing carbon in the ocean floor, seagrass meadows are essential in providing regulatory services such as improved water quality, sediment stabilisation and nutrient accumulation as well as improving marine biodiversity and habitat.

Protection against coastal flooding and erosion

The risks of accelerated sea-level rise with climate change has enhanced the associated increases in the frequency of extreme sea level, waves and the strength of storm surges, resulting in a higher intensity and frequency of flooding and erosion of vulnerable coastal areas. Vegetated coastal ecosystems are important in protecting the coast against flooding and erosion due to waves and storm surges under mean and extreme conditions, including hurricanes. Seagrasses have a particularly high capacity to dissipate wave energy, whereas salt marshes and mangroves have a high capacity to protect from surges. Moreover, these ecosystems often occur in juxtaposition with seagrass in sub tidal areas and salt marshes or mangroves (depending on latitude) in the intertidal zone, thereby increasing their combined effectiveness in protecting from waves and surges.

Sea level has been rising globally at an average rate of 1.6±0.2 mm yr^{-1} since 1901 (Church *et al.*, 2011). The long term tide data in coastal India showed that that the rate of sea level rise is one of the highest in West Bengal coast and it varied between 2-7.5 mm yr^{-1} whereas for the stations Mumbai and Cochin in west coast the rate of changes were +0.78 and +2.07 mm yr^{-1} and for Chennai and Vishakhapatnam in east coast the rate of changes were +1.06 and +1.00 mm yr^{-1} (Mandal *et al*., 2018). As a result, coastal flooding and erosion will be, and are already becoming, a major threat to coastal areas, demanding the introduction of sustainable measures to cope with this problem. Vegetated coastal habitats, through their capacity to provide coastal protection (Duarte *et al.,* 2013), could assist in mitigating the impacts of sea-level rise and the associated increase in wave action. The capacity of vegetated coastal habitats for protecting the coast against the different dynamics considered (waves, storm surges, tsunamis and currents) is highly dependent on both the large- and small-scale characteristics of these ecosystems. The geometry of each individual plant (roots, stems and canopies), its buoyancy, stiffness and degrees of freedom also affect wave attenuation. Hence, the capacity of vegetated coastal habitats to raise the sea floor at speeds that can match or exceed current sea-level rise, thereby counterbalancing the effect of sea level rise, allows them to remain effective in breaking waves with moderate to high scenarios of sea-level rise, in areas where subsidence and other processes that lower the elevation of the shore are not important. Fields of slender, vertical rigid or flexible elements such as seagrass, kelp, salt-marshes or mangroves are typical sources of this kind of dissipation.

Vegetated coastal habitats can thus dissipate wave energy through flow separation. Seagrass and other vegetated coastal habitats also provide protection by the dissipation of wave energy thanks to friction resulting from their presence increasing the bottom roughness, reducing near-bed flow velocity and elevating the bottom boundary layer. Mangrove ecosystems provide protection to people, livestock, property and other infrastructure in the eventuality of a storm. From the Indian sub-continent, one study stands out as having systematically estimated the storm protection value of mangroves. This is the study by Das (2007a & b) that has valued, using regression analysis, the number of human lives saved, number of livestock saved and damages to buildings avoided by mangroves in Kendrapada District in the event of the super cyclone that hit Orissa in October 1999. She estimated that a hectare of mangrove forestland stopped damages worth Rs. 18 Lakhs (USD 43,352) in the district during the super cyclone.

Climate change adaptation and mitigation

The conservation and protection of ecosystems that act as carbon sinks are among the cheapest, safest and easiest solutions to reduce greenhouse gas emissions and promote adaptation to climate change (Duarte *et al*., 2013).

A key adaptation strategy that needs to be enhanced to maintain climate services provided by coastal ecosystems is to limit coastal squeeze. Restoration of tidal wetlands can enhance global carbon sinks given their high productivity, high rates of carbon storage, potential for long-term sequestering as the volume of soil continues to increase over long time periods, and small or negligible emissions of methane and N_2O. Mangroves can successfully colonize intertidal muddy sediments and grow rapidly and, hence, are ideal for reforestation projects, while seagrass replanting is a viable option for degraded coastal waters.

High loss rates of vegetated coastal habitats, ten times faster than those of tropical forests, represent a major loss of natural CO_2 sink capacity and coastal protection and therefore contribute to the component of increased greenhouse gas emissions that is termed land-use change. Pendleton *et al.* (2012) estimated that 0.15–1.02 Pg CO_2 are being released annually from loss or conversion of vegetated coastal habitats, assuming that all of the organic carbon in biomass and the top metre of soils is lost.

This estimate, which carries considerable uncertainty, is equivalent to 3–19% of that from deforestation globally, and results in economic damages of US$6–42 billion annually from loss of CO_2 sequestration alone (Pendleton *et al.,* 2012), not accounting for the damages associated with the loss of coastal protection capacity. The use of vegetated coastal ecosystems to protect and restore lost CO_2 sink capacity and prevent the loss of deposits to mitigate climate change — Blue Carbon initiatives — was proposed in 2009. Avoidance of losses in vegetated coastal habitats that are threatened by local human activity (for example, aquaculture, waste-water discharges to coastal water, coastal tourism developments and reclamation) could help to maintain CO_2 sinks.

Adaptation strategies that include the conservation, restoration or introduction of vegetated coastal ecosystems provide a cost-effective option for addressing the increased risk from flooding and erosion under climate change in vulnerable areas. Conserving and restoring vegetated coastal habitats is also relatively inexpensive and is affordable to all countries, including developing ones. According to the International Federation of the Red Cross and Red Crescent, replanting mangroves in Vietnam has helped to reduce the cost of dyke maintenance by US$ 7.3 million a year for an investment of US$ 1.1 million over the period 1998–2002 (Duerta *et al*., 2013). For decades vegetated coastal ecosystems have remained the poor relations of biological conservation. However, recent findings on their remarkable capacity for CO_2 sequestration and storage, and their capacity for sediment accretion and coastal protection, have converged to identify these habitats as essential elements of a strategy that combines both climate change adaptation and mitigation.

Because coral reefs are insignificant carbon sources, they are not a useful management option in their own right for management of anthropogenic CO_2 emissions, but coral reefs, and the ecosystem goods and services they produce, are likely to benefit from other carbon sequestration initiatives that will slow and reduce ocean acidification (Smith and Gattuso, 2009).

Overall, mangroves, salt marshes, and seagrasses have a far greater capacity (per unit of surface area) than vegetation on land or kelp forests to achieve long-term carbon sequestration in sediments, arising in part from the extensive belowground biomass of the dominant vegetation and their capacity for continual accretion of sediments. The rate of carbon storage in the sediment by these ECEs is approximately 10 times the rate observed in temperate forests and 50 times the rate observed in tropical forests per unit area.

Blue biofuels

The development of biofuels from mass aquaculture of macroalgae isa new, vibrant area of research (Duarte *et al*., 2013), which has the potential to contribute to climate change mitigation. Macroalgal beds dominate the global area and production of vegetated coastal habitats (Table 1), but most macroalgal communities grow on hard substrates and do not contribute to carbon sequestration except for the biomass that may be exported to the deep sea. Yet macroalgae can play a role in mitigating climate change if either wild or aquaculture crops are used to derive biofuels. The production of 'blue biofuels' has many advantages over that based on land crops (green biofuels), generating multiple environmental and societal impacts. Blue biofuels do not compete for arable land and water with food crops, whereas green biofuels have co-opted both essential resources from agriculture, becoming a threat to food security. Moreover, blue biofuels are not currently staples of global significance, and so the production does not negatively affect food prices in the global market. In contrast, the development of green biofuels has diverted crops otherwise used as staples (corn or palm oil) away from the food market into fuel production, becoming an element in the recent global rise of food prices. Moreover, neither pesticides nor fertilizers are used in most seaweed farms, which remove nutrients often found in excess in coastal waters, generating environmental benefits in coastal areas affected by eutrophication.

Coastal ecosystems play a critical role in global climate and the carbon cycle by sequestering carbon. Carbon storage rates per unit area exceed those of terrestrial ecosystems. For the coastal ecosystems examined here, mangroves, salt marshes, and seagrasses combine to sequester a minimum of 136 000 tonnes C into long-term storage annually. Assuming prices of CO_2e from \$10 to \$90 per tonne, the value of the annual sequestration is \$5–45 billion. ECEs are large potential sources of GHGs if disturbed or mismanaged. Impacts on ECEs include conversion or degradation from anthropogenic activities, and also climate change. Anthropogenic activities include conversion and draining of salt marshes, deforestation of mangroves, and destruction of seagrass meadows through fishing and coastal development. Climate change-induced impacts include sea-level rise and ensuing coastal squeeze, and warming seas and ocean acidification. Possibilities for conserving and reclaiming ECEs can contribute significantly to global climate change mitigation. Mitigation possibilities include protecting ECEs through conservation initiatives, thereby maintaining existing stocks and carbon sequestration rates. Restoration projects for degraded ECEs can renew their ability to sequester.

Other ecosystem services

Fish is a valuable resource provided by the sea since it is an important source of food and nutrition for human beings. Total marine fish production in India was 3.56 million tonnes in 2019 and marine fish production has grown rapidly over time; increasing by a factor of six over the period 1950-51 to 2010-11. The coastline also accumulates valuable minerals formed during sedimentary processes due to gravity separation. The beaches and coastal sand dunes contain several heavy minerals, primarily ilmenite, rutile, garnet, zircon, sillimanite and monazite minerals were found in coastal states such as Andhra Pradesh, Kerala, Odisha and Tamil Nadu while Illmenite was also found in Maharashtra. The coastal states Gujarat and Tamil Nādu also produce salts from seawater and chemicals such as caustic soda, soda ash, etc. Apart from providing provisioning services, salt also provides recreational and cultural services. Salt pans, such as those in the Rann of Kutch in Gujarat and Tuticorin in Tamil Nadu have become tourist attractions. Other than its direct use in salt production, seawater is used to produce fresh water that is suitable for domestic consumption, irrigation and industrial use with the help of desalination technologies that essentially remove salt and minerals from saline water. Currently seawater desalination technology is the most widely used in the water scarce States of Tamil Nadu and Gujarat. At present, the installed production capacity stands at 2,97,435 m^3 per day in Tamil Nadu, and 2,90,392 m^3 per day in Gujarat (Kavi Kumar *et al*., 2016). Tamil Nadu and Gujarat account for 96.4 per cent of the total installed seawater desalination capacity in India (which is 6,09,927 m^3 per day). The biggest

30 desalination plants currently in operation in the country are the Reliance Industries, Jamnagar desalination plant in Gujarat (with a production capacity of 1,60,000 m^3 per day) and the Minjur and Nemmeli desalination plants in Tamil Nadu (each having a production capacity of 1,00,000 m^3 per day) Water is an important input requirement for the industrial sector as various industries require large quantities of water for their manufacturing process. Water use in thermal power plants, in particular, is significantly higher than that of other industrial sectors in India. For power plants located in coastal areas, water for cooling the condenser and plant auxiliaries is drawn from the sea or creek. Among other things, the seas provide us an opportunity to transport goods and people to various destinations via shipping. The economic importance of coastal zones lies in the fact that they provide livelihood support to fishers, and provide benefits of commerce, navigation and recreation. Most of the cultivated area in coastal region is predominantly mono-cropped mainly with rice cultivation. The coastal and island ecosystems offer vast scope of commercial use not only for vide varieties of fish, fruit and vegetable crops, but also plantation crops, spices, and medicinal plants. Multistorey plantation-based cropping systems and home gardens are dominant agricultural production systems. These are comprised of coconut, arecanut, oilpalm, cashew, cocoa, spices like cardamom, clove, black pepper, ginger, turmeric, and seed spices. Home gardens also consist of poultry, dairy, fishponds, and rice fields. Alley cropping, live fences, forest farming, or plantations under the shade of forest trees, and other agroforestry systems are found in the coastal and island regions.

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North Coastal Zone of A.P : Major Soil Types and Cropping Systems

K.V. Ramanamurthy, Ch. S. Ramalakshmi, A. Sireesha,
M.B.G.S. Kumari and P.V.K. Jagannadha Rao

ANGRAU, Regional Agricultural Research Station, Anakapalle

Soil is one of the most precious resource of the earth and it is a dynamic living layer forming the foundation of all eco- systems. Soil consists of products of weathering of rocks, intermixed with living organisms and the products of their decay, the moisture and air filling the interstitial space. Soils are usually differentiated into horizons of mineral and organic constituents of variable depths which differ from the parent material below in morphology, physical properties and constituents, chemical properties and composition and biological characteristics.

North Coastal zone is endowed with a wide variety of soils, ranging from less fertile coastal sands to fertile alluviums of the Sarada, Nagavali, Vamsadhara rivers developed from different parent materials. The five major groups of soils present in North Coastal Zone (Fig. 1) are Clay loams (*Inceptisols*) 42%, Sandy loams (*Inceptisols & Entisols*) 32%, Sandy clay loams (*Inceptisols*) 20%, Coastal Sands (*Entisols*) 5% and Alluvial soils (*Inceptisols*) 1%. Majority of soils are formed from granites, gneisses and schists.

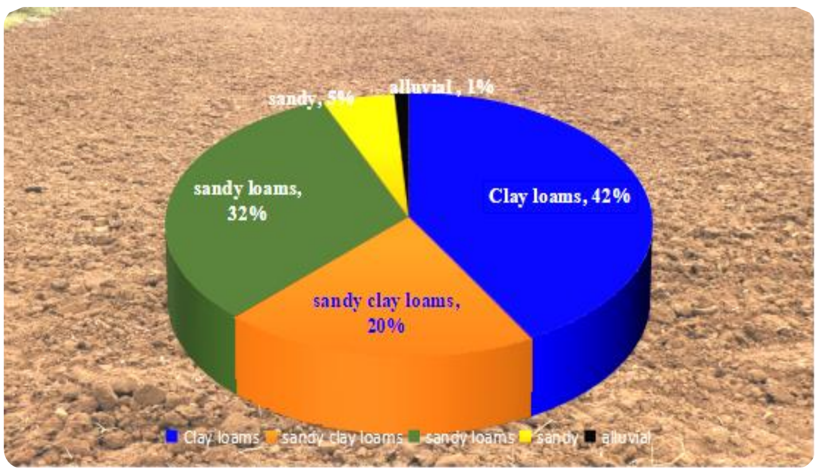

Fig 1. Major Soils of North Coastal Zone

Soil physicochemical and chemical properties of North Coastal districts:

Soils are acidic to moderately alkaline in reaction with normal salinity in all the districts, majority of the soils are neutral in reaction with normal conductivity (Table 1). Around 60% of the soils are low in organic carbon content (Table 2.), 25% of the soils are medium in OC content and 10-15% soils come under high OC content category. In all the three districts majority of the soils (89% in Visakhapatnam, 75% in Vizianagaram and 66% in Srikakulam) are low in available nitrogen status. In majority of the soils (60 to 86%) available phosphorus status is high in status. Available potassium status is equally grouped to low, medium and high in all the three districts. Regarding available micronutrients copper and manganese are sufficient in status, with regard to zinc and iron 15-20% of the soils are below the critical limits.

Table 1. Soil physicochemical and chemical properties of North Coastal districts

Property	Srikakulam		Vizianagaram		Visakhapatnam	
	Range	Mean	Range	Mean	Range	Mean
pH	4.22 - 8.28	-	7.2 - 8.6	7.61	5.12 - 8.25	-
EC ($dS\ m^{-1}$)	0.016 - 1.17	0.46	0.211 - 0.542	0.315	0.046 - 4.13	0.54
OC (%)	0.18 - 1.26	0.54	0.11 - 0.86	0.52	0.13 - 1.05	0.49
Available macronutrients ($kg\ ha^{-1}$)						
Nitrogen	75 - 412	224	122 - 264	215	68 - 365	235
Phosphorus	14 - 95.5	61.4	17.92 - 78.24	51.5	11.5 - 102.7	69.5
Potassium	22 - 980	285	189 - 444	224	34 - 1359	241
Available micronutrients (ppm)						
Zinc	0.26 - 1.26	0.67	0.44 - 1.13	0.65	0.41 - 0.91	0.68
Iron	2.62 - 19.50	7.80	1.18 - 10.15	6.25	1.89 - 17.50	6.10
Copper	0.88 - 2.45	1.85	0.53 - 4.06	1.32	0.56 - 4.50	2.10
Manganese	1.64 - 24.50	11.50	0.79 - 11.40	7.20	1.20 - 21.50	8.50

Table 2. Rating of soil properties in North Coastal districts

Property	Rating	Visakhapatnam	Vizianagaram	Srikakulam
		% samples		
Physicochemical properties				
pH	Acidic	02.1	05.6	07
	Moderately acidic	26.5	27.4	22
	Neutral	65.7	51.0	35
	Slightly alkaline	5.7	16.0	16
EC	Normal	68.0	78	77
	Slightly saline	20.6	12	03
	Moderately saline	11.4	5.0	20
Organic Carbon	Low	64	58	61
	Medium	26	27	22
	High	10	15	17

Property	Rating	Visakhapatnam	Vizianagaram	Srikakulam
		% samples		
Available Macro nutrients (kg ha^{-1})				
Nitrogen	Low	89	65	76
	Medium	11	35	24
	High	-	-	-
Phosphorus	Low	3	12	11
	Medium	21	27	30
	High	86	61	59
Potassium	Low	30.8	24	34.1
	Medium	31.0	43	37.6
	High	38.5	33	28.3
Available micronutrients (ppm)				
Zinc	Below critical limit	13	18	19
	Above critical limit	87	82	81
Iron	Below critical limit	08	21	12
	Above critical limit	92	79	88
Copper	Below critical limit	-	-	-
	Above critical limit	100	100	100
Manganese	Below critical limit	-	2	-
	Above critical limit	100	98	100

Genetic Classification of soils of North Coastal Zone

Twelve soil pedons in North Coastal Zone of Andhra Pradesh comprising of three districts *viz.*, Visakhapatnam, Vizianagaram and Srikakulam were exposed and studied morphometrically and classified all the pedons upto family level (USDA classification). All the pedons were confined to semi arid mansonic climate of low lying to plain lands. The soils were deep with coarse texture in sandy soils and clay loam texture in black soils (Fig. 2). Single grain to sub angular structure, wet consistence of non sticky, non plastic to plastic, sticky were the other features recognized. The results of physicochemical properties revealed that neutral to moderately alkaline soil reaction with non saline conductivity was observed in all the pedons. Among all the exchangeable bases calcium was dominant cation followed by Mg^{2+}, K^{+} and Na^{+}. All the surface layers exhibited low to medium in available nitrogen status and medium to high in available phosphorus and potassium status. Available copper and manganese in all pedons were above critical limits. Sufficiency in available zinc status was observed in all the surface layers (except pedon 1, 2 and 3). Pedons of Visakhapatnam district exhibited sufficiency in available iron status. The study area falls under ustic moisture, isohyperthermic temperature regime and has mixed mineralogy. The pedons of Visakhapatnam district key out as Fine loamy, mixed isohyperthermic, *Fluventic Haplustepts* and Coarse loamy, mixed isohyperthermic, *Fluventic Haplustepts.*

Fig. 2. Soil pedons of North Coastal Zone

Major Soil and Climatic Constraints in North Coastal Zone

Soil related constraints

- Low soil organic matter.
- Low water and nutrient holding capacity in majority of soils.
- Soil erosion and runoff losses in undulating and slopy lands.
- Surface crusting and hardening in some of the red sandy loam soils.
- High permeability and low water and nutrient holding capacity in coastal sandy soils.
- Poor drainage in alluvial soils.
- Sub-soil hardening in black clay soils.
- Saline and alkaline problems interspersed in different soil types.
- Majority of North Coastal zone soils are low in available nitrogen

Climate/weather related problems :

- Uncertain and erratic distribution of rain fall and occurrence of floods/ cyclones during **South west monsoon period**.
- Terminal moisture stress due to early cessation of monsoon
- Cool temperatures during December-January months leading poor crop growth

Production Constraints of major crops in North Coastal Zone

- Soils low in organic matter and with poor fertility and easily drying nature of soils with low retentive capacity of water and nutrients leading to lower yields.
- Less remunerative cropping system due to more area under rainfed conditions and small and marginal farmers.
- Non adoption of crop rotation leading to less productivity due to monocropping.

1. Paddy

- Heavy weed infestation in direct sown paddy.
- Late planting of over aged seedlings due to erratic rainfall distribution and late release of irrigation water.
- Poor maintenance of optimum population and non adoption of alley ways formation.
- No basal application of phosphatic fertilizers and potash and top dressing with complex fertilizers
- False smut, panicle mite, blast, sheath blight, BPH, stem borer and leaf folder are the major problems

2. Millets (Maize, Finger millet, Jowar and Bajra)

- Improper nutrient management.
- Limited use of fertilizers and herbicides.
- Stem borer and fall armyworm in Maize.
- Blast in finger millet

3. Mesta

- Limited availability of improved HYVs seed
- Weed menace
- Foot and stem rot and mealy bug are the major problems
- Poor adoption of improved retting technology

4. Sugarcane

- Poor ratoon management
- Poor cane propping and twisting to avoid lodging
- Early shoot borer and whip smut
- Non availability of labour for harvesting and high labour cost

5. Pulses

- Limited availability of High Yielding Varieties
- Yellow Mosaic Virus(YMV) and maruca
- Weed menace- specially Cuscuta and rangam minimu (*Vicia faba*)
- Wilt in low lying areas in red gram
- Yield losses due to terminal moisture stress in rice fallow pulses.

Cropping systems in North Coastal Zone

North Coastal Zone of Andhra Pradesh consists of Visakhapatnam, Anakaapalli, Vizianagaram and Srikakulam districts and some parts of Parvatipuram Manyam district. Iriigated lowland, Irrigated upland, Rainfed lowland and Rainfed uplands comprise the major farming situations of this zone. Paddy, Sugarcane Maize and Pulses (Blackgram and Greengram) are the major crops grown in this Zone while Sesame, Groundnut, Mesta, Bajra, Finger millet and other Small millets, Cowpea, Horsegram, Cotton, Sunflower are the other crops grown in this Zone.

The major farming situations and the efficient and diversified cropping systems suggested were detailed hereunder.

Table 1. Major farming situations in North Coastal districts

Srikakulam and some parts of Parvithupuram Manyam districts

Farming system	No. of Mandals	Area (ha)
Canalfed-Red clay loams	21	97914
Tankfed-red clay loams	21	39497
Canalfed sandy loams	5	23453
Tankfed - red sandy loams	6	12121
Rainfed - red clay loams	13	55071
Rainfed sandy soils	8	33890
Rainfed black clay	3	12709
Hill streams sandy clay loams	1	1055
Springed marshy lands (beela lands)	3	263

Vizianagaram and some parts of Parvithupuram Manyam districts

Farming system	No. of Mandals	Area (ha)
Tankfed sandy clay loam soils	33	59,845
Tankfed red sandy loam soils	33	26,990
Canalfed sandy clay loam soils	19	25,350
Canalfed red sandy loam soils	19	16,216
*R*ainfed red sandy loam soils	34	1,50,172
Rainfed sandy clay loam soils	34	1,08,157

Visakhakapatnam, Anakapalli and ASR districts

Farming system	No. of Mandals	Area (ha)
Tank Irrigation – Red clay loams	22	36539
Irrigated – Check dams	11	21989
Canal Irrigation – Clay loams	13	18590
Canal Irrigation – Alluvials soils	6	13353
Well Irrigation – Red Clay loams	22	10289
Rainfed – Red Clay Loams	11	97630
Rainfed – Red Sandy Loams	25	96656
Rainfed – Coastal Sandy soils	6	6856
	Total	301902

Table 2. Major Cropping systems of North Coastal Zone

Major Cropping systems in Srikakulam district

Irrigated Low land	Irrigated upland	Rainfed low land	Rainfed upland
Paddy –pulses Paddy –maize Paddy-groundnut Paddy-paddy (beela lands)	Paddy –pulses Paddy –maize Sugarcane Paddy-Finger millet Paddy-groundnut Cotton-pulse	Paddy Maize Cotton Mesta	Maize –pulses Groundnut Cotton Turmeric

Major Cropping systems in Vizianagaram district

Irrigated Low land	Irrigated upland	Rainfed low land	Rainfed upland
Paddy-pulses Maize – Maize Paddy – Maize Paddy – Finger millet Paddy- sunhemp Paddy-Pulses- Sesame Paddy-Paddy Sugarcane Sesame – Paddy – Pulses	Paddy-Pulses Paddy – Finger millet Paddy – Sesame Paddy-Maize Paddy – Pulses-Sesame Paddy-Ground nut	Maize – Pulses Maize – Horse gram Mesta-Horse gram Cotton – Fallow Red gram – Fallow Groundnut – Greengram	Sugarcane Paddy - Pulses Cotton – Fallow Maize – Pulses

Major Cropping systems in Visakhapatnam district

Irrigated Low land	Irrigated upland	Rainfed lowland	Rainfed upland
Paddy-Pulses Paddy-Sesame Paddy-Pulses-Sesame Paddy-Groundnut Sesame- Paddy-Pulses Sugacane(P) – Sugacane(R)-Sesame / Groundnut	Paddy –Pulses/Ragi/ Maize Paddy-Sesame Paddy-Vegetables Sugacane - Sugacane – Sesame/ Groundnut Paddy -Sugar cane Paddy-Groundnut Paddy-Pulses-Sesame Horticultural crops	Paddy-pulses Paddy-groundnut, Sugarcane(P)-ratoon-sesame or groundnut	Sugacane Bajra Paddy Redgram Groundnut Maize Ragi Horticultural Crops Casuarina Sericulture

Table 3: Efficient and Diversified Crops / Cropping systems in North Coastal Zone

S. No.	Farming situation	Soil type	Major crop and variety	Efficient and diversified Crop/ cropping system including horticultural crop along with variety that can be suggested
Srikakulam and parts of Manyam Parvatipuram districts:				
1.	Rainfed – Clay loams	Clay loams	Mesta Maize Groundnut Redgram Bt Cotton – **Varieties:** Mesta (AMV varieties) Groundnut (K6) Redgram (LRG-52) Cotton (Bt cotton)	Mesta (AMV-8) Mesta - Greengram (IPM 2-14) Mesta - Horsegram Maize - Greengram Maize - Horsegram Groundnut (Kadiri Lepakshi/ Nithya Haritha) or Groundnut – Greengram, Cotton + Redgram (6:2) Sorghum (NTJ-5) Cotton with pink worm management
2.	Tankfed – Red clay loams	Red clay loams	Paddy – Paddy **Varieties:** Rice (*kharif*), MTU 7029, MTU 1061, BPT 5204 MTU 1064, RGL 2537 Rice(*rabi*), MTU-1121 MTU-1156	Rice-Groundnut (Kadiri Lepakshi or Nitya Haritha instead of K6) Rice-Finger millet (Chaitanya, Bharathi, Indravathi)
3	Canalfed – Red clay loams	Red clay loams	Paddy-Pulse **Varieties:** Paddy (*kharif*), MTU 7029, MTU 1061, BPT 5204, MTU 1064, RGL 2537, Blackgram (LBG-752, PU-31 and Teegaminimu) Rice-Maize **Varieties:** Maize (Pvt.hybrids)	Rice-Blackgram (LBG - 787, TBG -104, LBG -752) Rice-Greengram (IPM 2-14) Rice – Rice fallow finger millet/ Sunnhemp (for seed production) in late sown conditions Rice-Zero tillage Maize Paddy-ID crops (Groundnut/Sunflower)
4	Irrigated sandy loams	Sandyloams	Groundnut/Maize **Varieties:** Groundnut JL-24, K-6 Maize: (Private hybrids)	Vegetables (Based on Market facility)

S. No.	Farming situation	Soil type	Major crop and variety	Efficient and diversified Crop/ cropping system including horticultural crop along with variety that can be suggested
Vizianagaram and parts of Manyam Parvatipuram districts:				
1	Canalfed - Red sandy loam soils	Red sandy loams	Paddy-pulses Sesame – Paddy – Pulses Paddy – Maize Maize – Maize, Banana, Vegetables, Papaya **Varieties:** Paddy : MTU-1121, BPT-3291, BPT-5204 Pulses: Blackgram LBG -752 and Theegaminumu Greengram : LGG-460	Green manure – Paddy –Pulses Green manure – Paddy –Maize Green manure – Paddy –Sunhemp seed production
2	Canalfed - Sandy clay loam soils	Sandy clay loams	Paddy- Maize Paddy-Pulses- Sesame Paddy-Paddy Sugarcane Paddy- Sunhemp Paddy – Finger millet Banana, Sesame – Paddy – Pulses **Varieties:** Paddy : MTU-1121, BPT-3291, BPT-5204 MTU-1061 MTU-1156 (Rabi) Pulses : Blackgram LBG-752 and Theegaminumu Green gram LGG-460 Sesame : Local, YLM -11 and YLM-17	Green manure – Paddy –Pulses Green manure – Paddy – Maize Green manure – Paddy – Sunhemp (SP) Green manure – Paddy – Finger millet
3	Tankfed – Red sandy loam soils	Red sandy loams	Paddy : MTU-1121, BPT-3291 Pulses : Blackgram (LBG-752 and Theegaminumu) Greengram - LGG-460 Sesame : Local, YLM -11 and YLM-17	Green manure – Paddy – Maize Green manure – Paddy – Fingermillet

S. No.	Farming situation	Soil type	Major crop and variety	Efficient and diversified Crop/ cropping system including horticultural crop along with variety that can be suggested
4	Tankfed – Clay loam soils	Sandy clay loams	Paddy-Maize Paddy – Pulses-Sesame Paddy-Ground nut Banana Tomato-Other vegetables Chillies-Leafy vegetables **Varieties:** Paddy : MTU-1121, BPT-3291, BPT-5204 Swarna (MTU-7029) Pulses :Blackgram LBG-752 and Theegaminumu Green gram LGG-460 Sesame : Local, YLM - 11 and YLM-17	Paddy – Pulses - Korra
5	Rainfed - Red sandy loam soils.	Red sandy loams	Mango, Cashew, Guava Maize – Pulses Cotton – Fallow Mesta-Horse gram Red gram – Fallow Groundnut – Greengram Maize – Horse gram Coconut **Varieties:** Pulses :Blackgram (LBG-752 and Theegaminumu) Green gram : LGG-460 Sesame : Local, YLM -11 and YLM-17 Mesta : AMV3, AMV-4 Groundnut : JL-24, TAG-24, K-6, K-7 Bold (R)	Green manure incorporation in orchard crops to improve soil fertility Pulses (Redgram) inter crop in Cotton Millet – Horsegram instead of mesta

S. No.	Farming situation	Soil type	Major crop and variety	Efficient and diversified Crop/ cropping system including horticultural crop along with variety that can be suggested
6	Rainfed - Sandy clay loam soils	Sandy clay loams	Sugarcane Paddy - Pulses Cotton – Fallow Maize – Pulses Coconut **Varieties:** Sugarcane : Viswamithra (87A298) Pulses: Blackgram (LBG-752 and Theegaminumu) Green gram (LGG-460) Sesame (Local, YLM -11 and YLM-17)	Inter crop of pulses in sugarcane in plant crop Replacement of old varieties (87A-298) of sugarcane Yellow mosaic tolerant pulses varieties (TBG-104, GBG-1, GBG-12 of Blackgram and LGG-574, WGG-42 of Greengram) Inclusion of Integrated farming system components wise Cattle, backyard poultry, sheep rearing, goat rearing etc.,
Visakhapatnam, Anakapalli and ASR districts:				
1.	Canal Irrigation – Alluvials soils	Alluvial soils	Paddy-Paddy , Paddy-Pulses, Paddy-Groundnut Paddy -Sesamum, Paddy – Pulses –Sesamum, Sugacane (P)-Sugacane (R)-Sesamum **Varieties:** Rice : RGL- 2537, BPT 5204, Sonamahsuri	Green manure / Greengram preceding to paddy, Redgram on field bunds Sugarcane intercropping with pulses. Bajra/Korra -Paddy
2.	Canal Irrigation – Clay loams	Clay loams	Sesame- Paddy -Pulses, Paddy-Ppulses Sugarcane, Paddy-Groundnut.Sugarcane (P) –ratoon - Sesamum or Groundnut	Bajra/Korra –Paddy Paddy-Maize/Bhendi/Sunflower Sugarcane (P)-Sugarcane(R) – Sunflower/Maize
3	Irrigated – Check dams	Red sandy clay loams	Paddy Sugar cane	Green manure/ Greengram preceding to paddy, Redgram on field bunds Sugarcane intercropping with pulses
4	Well Irrigation – Red Clay loams	Red clay loams	Paddy -Vegetables , Paddy -Groundnut Paddy –pulses/Ragi/ Maize, Sugacane (P)-Sugacane (R) -Sesamum Mulbery, Horticultural crops	Green manure/ Greengram preceeding to paddy Fodder crops in orchard crops Redgram on field bunds Sugarcane intercropping with pulses

S. No.	Farming situation	Soil type	Major crop and variety	Efficient and diversified Crop/ cropping system including horticultural crop along with variety that can be suggested
5	Tank Irrigation – Red clay loams	Red clay loams	Paddy-Pulses-Sesamum Sugacane (P)-Sugacane (R) - Sesame Paddy - Pulses, Paddy - Groundnut Paddy - Sesamum Sugarcane (P)-Sugacane (R) -Sesamum or Groundnut	Green manure/ Greengram preceeding to paddy, Paddy with redgram on field bunds Paddy - Rice fallow Ragi
6	Rainfed – Red Clay Loams	Red clay loams	Paddy - Pulses, Paddy -Groundnut, Sugarcane(P)-Sugarcane(R) - Sesamum or Groundnut	Green manure/ Greengram preceeding to paddy, Dry direct seeding of paddy Sugarcane (P)-Sugarcane(R) – Blackgram/Maize/Sunflower
7	Rainfed – Red Sandy Loams	Red clay loams	Bajra, Paddy, Redgram, Groundnut, Maize Sugacane (P)-Sugacane (R)- Sericulture	Redgram+Maize, Ragi+Redgram, Maize-Greengram/Blackgram Bajra+Redgram
8	Rainfed – Coastal Sandy soils	Sandy laoms	Ragi, Horticultural Crops Casurina	Jowar, Ragi, Improved varieties of coconut, cashew

Integrated Farming System: An Approach For Sustainable Productivity in Coastal Agro-Ecosystem

Manukonda Srinivas, K. Dakshina Murthy, P. Munirathnam, B. Anusha, G. Jogi Naidu and M. Bharathalakshmi

AICRP on IFS Scheme, Regional Agricultural Research Station, Maruteru – 534 122
West Godavari District, Andhra Pradesh
Acharya N.G. Ranga Agricultural University
Corresponding Author: manukonda.s@angrau.ac.in

The human population of India has increased to 1.385 billion at a growth rate of 1.2% in 2020 and is estimated to increase further to 1.52 billion by 2036 with 70% of increase in urban areas. On the other hand, our national food grain production for past 3-4 years is hovering around 234 million tones. There are projections that demand for food grains would increase to 355 million tonnes in 2030. The average size of land holding has declined to 1.21 ha during 2009-10 from 2.30 ha in 1970-71. Declining size of land holdings without any alternative income augmenting the opportunity is resulting in fall of farm income and causing agrarian distress. The current scenario in the country indicates that area under cultivation may further decrease and more than 20% of current cultivable area will be converted into non-agricultural purposes by 2030 (Gill *et al*., 2005, Manukonda *et.al*., 2022).

Small and marginal farmers are the core of Indian agricultural rural economy consisting 85% of the total farming community but possessing only 44% of the total operational land holdings control the core Indian rural economy (Govardhan *et.al*., 2020). The declining trend of per capita land availability poses a serious challenge to the sustainability and profitability of small and marginal farmers. Also, in agriculture majority of the farm holdings are dry lands and even irrigated areas depend on the monsoon. In this context, if farmers are only concentrated on crop production they will be subjected to a high degree of unsustainability in income and employment. The income from cropping system only for an average farmer is hardly sufficient to sustain his family. Hence, it is imperative to manage certain strategies for the rural marginal farmers by combining the different enterprises to ensure the profitability while preserving the environment and increase the productivity and supplement the income.

There is a pressing need to meet the food grain requirements of the growing population and to sustain a reasonably higher productivity level. Crop diversification has been recognized as an effective strategy for achieving the objectives of food security, nutritional security, soil health, poverty alleviation, employment generation and judicious use of available natural resources like land and water. The need for farming systems approach in the present scenario is mainly due to high cost of farm inputs, fluctuation in the market price of farm produce, risk of crop harvest due to climatic vagaries and biotic factors.

Environmental degradation, depletion in soil fertility and productivity, unstable income of the farmer, fragmentation of holdings and low standard of living add to the intensity of the problem.

To meet the multiple objectives of poverty reduction, food security, competitiveness and sustainability, several researchers have recommended the Farming Systems Approach to research and development. Integrated farming system is a multi-disciplinary holistic approach to solve the problems of small and marginal farmers.

Farming Systems Approach and What it does

It is an approach for developing farm - house hold systems, built on the principles of productivity, profitability, stability and sustainability. All the components are complimentary and supplementary to each other and the development process involves participation of rural communities. The Farming Systems Approach emphasizes understanding of farm house hold, community inter linkages, reviews, constraints and assesses potentials and it combines improvements desired from better technology. It needs efficient support services and requires better policies. It is continuous, dynamic and interactive learning process based on analysis, planning, testing, monitoring and evaluation.

Farming systems: Concept, Objectives, Principles, Classifications and Strategies

i) Concept of Farming Systems

Farming system concept was developed in 1970 and it is designed to understand farmer priorities, strategies and resource allocation decisions and is an integrated set of activities that farmers perform in their farms under their resources and circumstances to maximize the productivity and net farm income on a sustainable basis. In other words, it is an appropriate mixes of farm enterprises and the means available to the raise them for profitability. In its real sense it will help in lifting the economy of agriculture and standard of living of the farmers of the country as a whole. Its goal is to develop sustainable land use system which will optimize resource use and increase income and employment for farm families. The integration is made in such a way that the output of one enterprise/ component should be the input for the other enterprises with high degree of complementary effects (Panke *et al.*, 2010). Crop residues can be used for feeding to animal, while enhancing the agricultural productivity should be done through utilization of manure from livestock by intensifying nutrients that improve soil fertility as well as reducing the use of chemical fertilizers (Gupta *et al.*, 2012).

Farming System represents an appropriate combination of farm enterprises (Cropping systems horticulture, livestock, fishery, forestry, poultry etc.,) and the means available to the farmer to raise them for profitability. It interacts adequately with environment without dislocating the ecological and socio-economic balance on one hand and attempts to meet the national goals on the other.

ii) Specific Objectives

1. To identify existing farming systems in specific areas and access the irrelative viability.
2. To formulate farming system model involving main and allied enterprises for different farming situations.
3. To ensure optional utilization and conservation of available resources and effective recycling of farm residues within system
4. To maintain sustainable production system without damaging resources/environment
5. To rise overall profitability of farm household by complementing main /allied enterprises with other

iii) Key principles of Farming systems are

- Cyclic: Farming system is essentially cyclic (organic resources– livestock –land–crops) Therefore, management decisions related to one component may affect the others.
- Ecologically sustainability: Combining ecological sustainability and economic viability, the integrated livestock–farming system maintains and improves agricultural productivity while also reducing negative environmental impacts.
- Rational: Using crop residues more rationally is an important route out of poverty. For resource-poor farmers, the correct management of crop residues, together with an optimal allocation of scarce resources, leads to sustainable production.

iv) Criteria for classification of Farming systems

Available natural resource base, including water, land, grazing areas and forest;

climate of which altitude is one important determinant; land scape, including slope; farm size, tenure and organization; dominant pattern of farm activities and house hold livelihoods, including field crops, livestock, trees, aquaculture, hunting and gathering and processing off farm activities; and taking into account the main technologies used, which determine the intensity of production and integration of crops, livestock and other activities.

Farming systems can be divided into eight broad categories depending on climate, resources and so on, available to the farmers in the regions. They are:

1. Irrigated farming systems
2. Wetland rice-based farming systems
3. Rainfed farming systems in humid areas of high resource potential
4. Rainfed farming systems in steep and high lands
5. Rainfed farming systems in dry or cold low potential areas
6. Dualistic (mixed large commercial and small holder) farming systems
7. Coastal artisanal fishing
8. Urban based farming systems, typically focused on horticulture and livestock production.

Key role of Farming Systems Approach in Agriculture is

- Food security
- Provide balanced food
- Quality food basket
- High productivity and enhanced farm income
- Effective recycling of resources
- Minimizing environmental pollution
- Employment generation

Farming Systems Strategies are

In view of serious limitations on horizontal expansion of land and agriculture, only alternative left is for vertical expansion through various farm enterprises required less space and time but giving high productivity and ensuring periodic income specially for the small and marginal farmers located in rainfed areas, dry lands, arid zone, hilly areas, tribal belts and problem soils. The location specific systems must be developed based on the available resources which will result into sustainable development of the region (Dashora and Hari, 2014).

The following farm enterprises could be combined:

- Agriculture alone with different crop combinations
- Agriculture+ Livestock
- Agriculture + Livestock + Poultry
- Agriculture + Horticulture + Sericulture
- Agroforestry+ Silvipasture
- Rice + Fish culture
- Rice + Fish + Mushroom cultivation
- Floriculture + Apiary (bee keeping)
- Fishery+ Duckery+ Poultry

Factors influencing Integration of Farm Enterprises

1. Soil and climatic features of the selected area.
2. Availability of the resources, land, labor and capital.
3. Present level of utilization of resources.
4. Economics of proposed integrated farming system.
5. Managerial skill of farmer.

Integrated Farming Systems (IFS) Approach

IFS is a component of Farming system research introduces a change in farming techniques for maximum production in the cropping pattern and takes care of optimal utilization of resources. The farm wastes are better recycled for productive purposes in the IFS. Unlike the specialized farming system, IFS's activity is focused round a few selected, inter-dependent; inter-related and often inter-linking production systems based on few crops, animals and related subsidiary professions. IFS envisage harnessing the complementarities and synergies among different agricultural subsystems, enterprises and augmenting the total productivity, sustainability and gainful employment.

An intensive IFS addresses two issues; reduction of risk with the monoculture activities and promoting enterprise diversification, value addition and development of alternative income sources with efficient utilization of farm resources and it brings about enterprise diversification for sustainability and additional benefits, better management of important farm resources like land, labour and capital etc., provides an opportunity for effective recycling of the product and by–products, helps to generate flow of cash to the farmers round the year by way of disposal of milk, fruits, fuel, manure etc., beside other agricultural output.

Goals of IFS are

- Maximization of yield of all component enterprises to provide steady and stable income.
- Rejuvenation of system's productivity and achieve agro-ecological equilibrium
- Avoid the build-up of insect-pests, diseases and weed populations through natural cropping system management and keep them at a low level of intensity.
- Reducing the use of chemicals (fertilizers and pesticides) to provide chemical-free healthy produce and environment to the society (Manjunatha *et. al*., 2014).

Recommendations on existing farming system models in the farmer fields are

- The farmer should be actively involved in all kinds of agricultural operations preferably with his family members instead of engaging labourer and paying high wages.
- Size of the unit should be at least one acre/hectare with diverse components.
- It should be a closed system with only marginal external inputs from outside.
- No model can be said to be complete or the most profitable which can be recommended at all locations.
- Model should be formulated taking into account the soil type, climate and resources of the farmers and the marketability of the commodities produced in the system.
- The model should ideally be a flexible one with scope for modifications.

Integrated Farming System Models suitable for different farming situations of Coastal Agro-Ecosystem are

i) IFS Model suitable for Wet land situation in Coastal Ecosystem:

(Cropping + Horticulture + Fishery + Poultry + Mushroom Cultivation)

#	Crop Components	Area (ha)
A.	**Crops**	
1.	Rice-Rice-Maize/ Sweet corn	0.13 ha
2.	Rice-Rice-Groundnut	0.10 ha
3.	Maize-Rice-Sesame	0.10 ha
B.	**Fish Pond**	
1.	Trench farming (0.04 ha) / Sole fish farming	0.20 ha

#	Crop Components	Area (ha)
C.	**Horticulture crops**	
1.	Vegetable Cultivation/ Flower crops	0.20 ha
2.	Boundary Plantations: Coconut/ Bamboo/ Neem etc.,	0.05 ha
3.	Fruit Crops: Banana/ Mango/ Guava/ Papaya	0.10 ha
D.	**Dairy**	
1.	Dairy unit @ 3-4 Buffalos/ Cows	0.10 ha
2.	Biogas unit @ 2 m^3 capacity	
3.	Oster Mushroom production @ 1.5 kg/day	
E.	**Other Components**	
1.	Back yard Poultry: 100 Nos (Desi/ Aseel/ Kadaknath)	0.02 ha
2.	Vermicompost/ FYM production unit.	
	Total	**1.00 ha**

- **Cropping :** IFS model for wet land situation with cropping, fish culture, poultry and mushroom production (Cropping 0.33 ha, fish pond 0.04 ha or 0.20 ha).
- **Fish production:** Fish Pond in an area of 0.04 ha was excavated to a depth of 1.5 m. Fifteen days old fingerlings of silver carp/rohu/mrigal/grass carp at 4:2:3:1 ratio with a total of 7500 fingerlings/ha were stocked. Fish was harvested from 10th month.
- **Poultry production:** A poultry shed of plinth area of 2.2 m^2 was prepared at one corner of the pond. Bottom of shed was provided with welded mesh so that poultry dropping can easily fall into pond. This will serve as feed for fish.
- **Mushroom production:** Mushroom production was done in 5 x 3 m shed. Rice straw was used to produce oyster mushroom.

Economics:

- Additional revenue from IFS over conventional practice – Rs. 1,25,000/ha/year
- Additional employment generation in IFS – 350 Man Days/ha/year

ii) Suitable IFS Model for Irrigated situations in Coastal Ecosystem:

(Cropping + Cattle + Horticulture + Mushroom cultivation)

#	Crop Components	Area (ha)
A.	**Irrigated crops**	
1.	Rice/Maize/Cotton - Sunflower/Sweet corn - Green gram/Cowpea	0.30 ha
2.	Rice-Pulses-Rice-Fodder cowpea	0.10 ha
B.	**Fodder crops**	
1,	Napier grass (CO-1)/ Hybrid Napier/ Multi cut fodder Jowar	0.10 ha
C.	**Horticulture crops**	
1.	Vegetable Cultivation/ Flower crops	0.20 ha
2.	Boundary Plantations: Coconut/ Bamboo/ Neem etc.,	0.05 ha
3.	Fruit Crops: Banana/ Mango/ Guava/ Papaya	0.10 ha
D.	**Dairy**	
1.	Dairy unit @ 3-4 Buffalos/ Cows	0.10 ha
2.	Biogas unit @ 2 m^3 capacity	
3.	Mushroom production @ 1.5-2.0 kg/day	
E.	**Other Components**	
1.	Back yard Poultry: 100 Nos (Desi/ Aseel/ Kadaknath)	0.05 ha
2.	Vermicompost/ FYM production unit.	
	Total	**1.00 ha**

Economics:

- Additional revenue from IFS over conventional practice - Rs. 75,000/ha/year
- Additional employment generation in IFS – 255 Man Days/ha/year

iii) Suitable IFS Model for rainfed situations in Coastal Ecosystem:

(Rainfed cropping + Sheep/Goat/Poultry + Dryland Horticulture)

Rainfed region with annual rainfall > 750 mm and growing period > 200 days.

1. Interspace between fruit trees were sown with pulses and vegetables.
2. Alley cropping in between Horticulture plantations
3. Depending on water availability Dairy/Fishery/Piggery may be included.

#	Crop Components	Area (ha)
A.	**Rainfed crops**	
1.	Cotton - Green gram - Maize + Fodder Cowpea - Onion	0.40 ha
2.	Rainfed Rice/ Maize/ Groundnut/ Millets + Sunflower – Maize/ Sweet Corn + Fodder cowpea- Summer cotton + green gram	0.10 ha
B.	**Tree/grass fodder**	
1.	Fodder crops (COFS 29, COFS 31 and Multicut Jowar SSG 59-3)/ Napier grass (CO-1)	0.10 ha
2.	150 trees of Leucaena (Planted on bunds) and Lucerne	0.04 ha
C.	**Horticulture crops**	
1.	Vegetable Cultivation/ Flower crops	0.16 ha
2.	Boundary Plantations: Teak/ Rose wood/ Neem etc.,	0.05 ha
3.	Fruit Crops: Mango/sapota/guava/papaya/pomegranate/ber etc.	0.10 ha
D.	**Other Components**	
1.	Rearing of Goat/ Sheep: (9 Female + 1 Male) in shed of size 8 x 5 m	0.05 ha
2.	Back yard Poultry: 50 Nos (Desi/ Aseel/ Kadaknath)	
3.	Vermicompost/ FYM production unit.	
	Total	**1.00 ha**
	Farm Shed	
	Dairy unit @ 2 Buffalos/ Cows	
	Biogas unit @ 2 m^3 capacity	
	Mushroom production @ 1.5-2.0 kg/day	

Economics:

- Additional Income from IFS over Conventional practice - Rs. 50,000/ha/year
- Additional employment generation in IFS - 151 Man Days/ha/year

Research on Integrated Farming Systems at ANGRAU-RARS, Maruteru AP

The preliminary research investigations under IFS approach advocates the benefits of farm productivity improvement by 30-50% and more than double increase in the employment generation than arable farming alone, depending upon the number and kind of enterprises integrated. Integrated farming system works as a system of systems, which ensure that the wastes and/ or by product from one enterprise become a resource for another enterprise with high degree of synergy and complimentary effects on each other.

By analysing these facts an improved IFS model was designed, tested and validated for 0.6 ha (1.5 acre) area to support a farm family of five members at RARS, Maruteru under AICRP on IFS Scheme with the main objective of generating adequate income and employment for the small and marginal farmers and identifying appropriate cropping systems with high productivity which suits the specific needs of the Godavari zone and efforts will be made with the aim to double the real farm income. The IFS model, presently have different enterprises *viz.,* crop production, horticulture, dairy, fishery, poultry, boundary plantation and vermicompost/ recycling of farm waste (Figure 1). This IFS model is eco-friendly having great potential to small and marginal farmers of Andhra Pradesh.

Fig. 1. Wetland IFS Model developed at ANGRAU- RARS, Maruteru, AP.

Table. 1 Details of Wetland IFS unit of ANGRAU-RARS, Maruteru

Farming System	Area (ha)	Details
Crops / cropping systems	2500 m^2	Rice-Rice-Pulses, Maize-Green gram - Sesamum, Red gram + Greengram-Sweet corn Fodder Jowar - Cowpea-Fodder Maize
Horticulture-fruit orchards	1450 m^2	Fruit crops: Banana, Guava, Papaya, Mango, Apple Ber, Pomegranate, Pomelo Citrus, Vegetables: Bhendi, Cluster Bean, Gourds, Brinjal, Tomato and Green chillies Flower crops: Mari gold, Crossandra
Dairy	250 m^2	Two Desi Cows and One Calf
Poultry	40 m^2	30 Nos Kadaknath chicks
Fishery	1200 m^2	550 number fingerlings in trench fish farming
Mushroom	60 m^2	2 units
Boundary plantation	100 m2	Rose wood, Sapota, Mango and Guava
Production from IFS on equivalent basis (t) (Mention the base crop)	-	12.10 tonnes from 1.5 acres Base crop: Rice
Market input cost excluding labour (Rs)	-	Rs. 1,52,158/-
Cost of purchased animal feed (Rs)	-	Rs. 15,000/-

Farming System	Area (ha)	Details
Value of recycling excluding family labour (Rs)	-	Rs. 8,500/-
Cost of hired labour (Rs)	-	Rs. 7,500/-
Cost of family labour (Rs)	-	Rs. 2,19,000/-
Total Cost (Rs)	-	Rs. 40,500/- (excluding family labour)
Net returns (Rs)	-	Rs. 1,11,658/-
Net returns per rupee invested	-	Rs. 2.76/-
Initial Soil organic carbon (%)	-	1.02
Soil organic carbon (%) during 2020-21	-	1.24
Employment generation (family + hired) (man days)	-	464

- Among all the components in IFS unit, dairy component share is 44% and Horticulture and Fish component share is 13% each. Value addition itself contributes 12% of overall profit (Table 1).
- This clearly shows that in wet land IFS model unit dairy, fishery and horticulture becoming 70% of the overall profits and these three components integration become more viable and sustainable.
- Without much effort value addition like selling of milled rice is much more economical and ensure additional profits.

Table 2. Carbon Dioxide estimation from wetland IFS model:

IFS model details	Year	Estimation Unit	Source	Sink	Net
Cropping systems (0.12 ha) + Dairy (2 Desi cows) + Fishery (0.08 ha) + Poultry (30 Nos) + Horticulture (0.12 ha) + Compost /others (0.14 ha)	2018-19	kg CO_2 equivalent	3385.6	8096.7	-4711.1
	2019-20	kg CO_2 equivalent	3502.2	8544.2	-5042.0
	2020-21	kg CO_2 equivalent	4095.1	8792.0	-4696.9
		Mean	**3661.0**	**8477.6**	**-4816.6**

- Mean Net GHG emission of three years of IFS unit was – 4816.6 CO_2-e which indicates the established IFS model at RARS, Maruteru is more suited for environmental sustained and eco-friendly unit (Table 2). Further, there is an ample scope to include more number of components for better income generation and recycling of components. Hence, the IFS model of RARS, Maruteru sinks more carbon in the system and emits less CO_2 (Figure 2).

Fig. 2. Arial view of Wetland IFS Unit of ANGRAU - RARS, Maruteru, A.P.

Constraints for implementation of farming system models are

- Lack of farmer's participatory approach
- Inadequate training and planning on IFS models
- Initial investment cost
- Through knowledge on other enterprises
- Selection of good varieties and breeds
- Animal health issues and medication
- Concentrated feed and fodder for live stocks
- Lack of rural infrastructure,
- Policy implementation
- Socio-economic constraints
- More so interest of the family members

Future research thrust

- Need to study the sustainability of the identified systems under different topographical situations in the long run including high value crops.
- Need to study the nutrient dynamics of soil with continuous cropping and recycling of manurial resources with different systems over time.

- Modeling of the identified farming system options to suit a given agro–climatic and socio–economic situation.
- Need to identify the constraints in adoption of identified farming systems by the farmers for further refinement.

Conclusion

Efficient utilization of scarce and costly resources is the need of the hour to make crop production a viable pre-position in the present-day competitive scenario. Improving the integrated approach not only enhances farm income but also overcomes environmental pollution. A better planning and utilization of all available resources will make bright prospects for the farm economy as a whole. Lastly and importantly **TAILOR-MADE IFS MODELS** are only the option for better success at farmer's end.

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Use of Crop Models for Risk Assessment and Climate Change Adaptation Across Scales

K. Dakshina Murthy, M. Srinivas, Ch. Sreenivas and M. Bharata Lakshmi

Regional Agricultural Research station, Maruteru – 534 122
West Godavari District, Andhra Pradesh
Acharya N.G. Ranga Agricultural University

Agriculture and allied sectors are important sources of livelihood for most of the 833 million people residing in rural India. Agriculture contributes 17.3% to the Gross Domestic Product (GDP). Although this is less compared to the service sector's contribution at 53.6%, Agriculture plays a critical role in food, nutritional security and rural employment. India remains committed to maintaining food security for its population through various government programs. Indian agriculture faces a serious threat from climate change that may lead to severe challenges in ensuring food security for its growing population. Climate change impacts are expected to reduce food production, leading to higher food prices, reduced consumption and increased number of people with malnourishment and hunger. Several researchers have studied the impacts of climate change on various crops and their productivity using different methodological approaches. They have used either process-based biophysical models or economic and statistical models

Climate risk assessment and management

Climate risk management is one of the major challenges to achieving food security and development in India and large parts of sub-Saharan Africa and also in the case of Australia. Climate-induced production risk associated with the current season-to-season variability of rainfall is a major barrier in making rainfed agriculture sustainable and viable farm business. Since season outcomes are uncertain, even with the best climate information, farmers have limited flexibility in applying management with confidence. Infact in risky environments, farmers most often respond by adapting a risk averse strategy and are reluctant to invest in even risk reducing measures (Leathers and Quiggin 1991). Predictability of climate at regional scale presents an opportunity for agricultural systems modelers to identify feasible alternative cropping options to minimize the climate risks, improve productivity and food security. Comprehensive systems simulation models are available and validated in semi-arid regions by researchers as tools of integrated interdisciplinary research knowledge. The Agricultural Production Systems sIMulator (APSIM) is one such model that has crops and systems management modules developed and validated for Indian semi-arid farming systems (Nageswara Rao *et al.,* 2004). Most of the modules had been modified, tested and enhanced to suit for semi-arid tropical conditions (Carberry *et al*., 1989, Whitbread *et al*., 2010) with many crop and management modules developed with ICRISAT research inputs.

Recent advances in simulating climatic conditions using Global Coupled Ocean Atmosphere General Circulation Models (COAGCMs) provides an opportunity to develop location specific down scaled seasonal climate forecasts months in advance. By linking these forecasts with agricultural systems models, it is possible to identify best possible crops and management options that perform well under the predicted seasonal conditions. Such management options will greatly assist farmers in managing their farms more efficiently and productively with low risk.

Climate variability and change impacts on crop production

Climate variability is a major source of risk in food production in the semi-arid tropics which is home to almost 2.5 billion people. With other biophysical, socio-economic and political factors, climate risk contributes enormously to food insecurity, economic losses, and poverty. Climate-induced production risk is a particular challenge for those whose livelihoods depend on rainfed agriculture in marginal high-risk environments such as semi-arid tropics. This situation is likely to be exacerbated by the projected changes in climate. Past and ongoing work has enabled us to understand the impacts of climate variability and change on smallholder agriculture and the perceptions and coping strategies being adopted by farmers. Research has also identified a number of potential options that can contribute to improved management of agricultural systems under variable climatic conditions. Agricultural productivity and profitability under these high climate risk environments therefore depend on how well farm activities are planned and executed. Pilot studies have clearly established the usefulness of climate information for smallholder decision-making, but the operational delivery, at scale, of actionable information products requires context-specific granularity, timeliness, formatting and, importantly, feedback loops for continuous learning.

Crop Simulation Models

Comprehensive systems simulation models are now available to researchers as tools of integrated interdisciplinary research knowledge. The Agricultural Production Systems sIMulator (APSIM), Decision support system for Agro Technology Transfer (DSSAT) and several others have been parameterized, tested and enhanced to simulate farming systems in several parts of the world.

Improving climate information is only half the battle; the other half is ensuring that farmers get the information in ways that they can use it in support of their farming decisions. It should be provided on a narrow spatial and time scale relevant to the local situation. Given the large spatial variation of rainfall and soils in India, appropriate strategies should necessarily be location specific. Seasonal climate forecast based decision making is an adaptation strategy against climate variability and change to minimize the risks of crop losses, and improve crop productivity in favourable seasons. The application of seasonal climate forecasts for smallholder farmers' crop management decisions was firstly implemented in Tamil Nadu (Selvaraju *et al*., 2004). In Andhra Pradesh, application of seasonal climate forecast based crop management options for farmers decision-making was implemented during 2003 in Kurnool and Anantapur districts (Nageswara Rao *et al*., 2007). However, literature on implementation of seasonal climate forecast applications for participatory crop management by smallholder farmers in India is limited.

Use of crop simulation models for climate change impact studies

Crop simulation and other autoregressive models have been widely used to examine the impacts of abiotic stresses such as long-term changes in surface temperatures, carbon dioxide (CO_2) emissions and rainfall on various crops. Recent studies using crop simulation models to examine groundnut yields in 2050 report as much as a 25% decrease in yields compared to 2010 (Singh *et al*., 2014). However, these results were obtained without considering technological changes and impacts of long-run drivers such as growth in incomes, area, production and crop yields. Over the years, new crop technologies may have been adopted by farmers in response to changes in population, income, in addition to climate. These factors should be considered while assessing impacts of climate change on various crops and cropping systems as they have a significant effect on consumption and expenditure on food commodities. Globally, by 2050 yields of major crops such as maize, rice, wheat, and soybean will be around 11% lower due to the effects of climate change combined with economic responses. When compared with climate alone, the yield decline will be 25% (Islam *et al.*, 2016). These studies indicate the importance of linking climate, crop and economic models to understand the magnitude and trade-offs of climate change.

Integrated assessment of climate change impacts

Several researchers have quantified the impacts of climate change on several crops and regions, most of the studies have focused on assessing biophysical impacts without considering economic factors and future pathways. Therefore, it is critical to understand how climate change impacts will influence developing countries adaptation and mitigation measures and assess the impacts on crop production and prices. The issue of how climate change may affect agricultural productivity and food security has been addressed using a range of tools. Although the general research question may be the same, the output depended on the methodology used and the power of that tool. Crop modeling work simulates how yields change under different conditions, whether using historical data or future projections. Economic modeling studies examine how yields change when market interactions are considered and how this affects prices, production, consumption, and trade.

Process-based and statistical approaches often rely on a large set of projected climate change effects from various GCMs that take into account temperature, precipitation, water stresses, and other variables. The studies generally used GCMs specific to their location or a median of the total available GCMs

In a case study on groundnut to examine the biophysical and social economic impacts of climate change on groundnut production and prices and to provide a comprehensive analysis of how agriculture and the food system will be affected by climate change. Using projected climate data for India, estimated the biophysical impacts of climate change on groundnut during mid-century using representative concentration pathway (RCP 8.5) scenario and examined the impacts of changes in population and income besides environmental factors on groundnut productivity. This is to highlight the importance of holistic assessment of biophysical and socioeconomic factors to better understand climate change impacts. Modelled projections show that by 2050, climate change under an optimistic scenario will result in−2.3 to 43.2% change in groundnut yields across various regions in India when climate alone was factored in. But the change in groundnut yields ranged from −0.9% to 16.2% when economic (population and income) and market variables (elasticities, trade, etc.) were also considered. Similarly, under pessimistic climate change scenario, the per cent change in groundnut yields would be −33.7 to 3.4 with only the climate factored in and −11.2 to 4.3 with the additional economic and market variables included. This indicates the sensitivity of climate (Kadiyala *et al.*, 2021)

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Innovative Sustainable Nutrient Management Strategies in Rice Production for Andhra Pradesh

Ch. Srinivas, A. Sireesha, T. UshaRani, D. Srinivas, M. Srinivas,
K.M. Dakshinamurthy, T. Srinivas, G. Jogi Naidu and M. Bharathalakshmi

Regional Agricultural Research Station, Maruteru
Acharya N.G. Ranga Agricultural University

Rice is the major staple food crop of India which ranks second in production of paddy and rice next to China. While India ranks first in list of principal rice exporting countries worldwide in 2021-2022 (18,750 tmt). To sustain this higher production efficient nutrition need to be provided to rice crop. Some of the innovations need to be adopted by the farming community are listed based on the studies conducted at Regional Agricultural research Station (RARS), Maruteru.

Long term Effect of Fertilization Experiences

Long term soil fertility management studies in low land rice soils of Godavari delta under rice-rice cropping system being conducted at RARS, Maruteru since 1989.

Fig. 1. Aerial view of experimentation at RARS, Maruteru

Results after 32 years of experimentation revealed (Table 1) that (i) Application of 100% NPKZnS + FYM @ 5 t ha^{-1} recorded highest grain yield and organic carbon content. This signifies the conjunctive use of organics and inorganics in increasing grain yield and soil productivity also. (ii) Application of 100% NPKZnS found on par with of 100% NPKZnS + FYM @ 5 tha^{-1} in grain production only. (iii) Application of balanced fertilization @ 100% NPKZnS found superior to imbalanced fertilization, (iii) Application of FYM @ 10 t ha^{-1} was found on par with 100% NPKZnS in grain production during *kharif* only and registered higher organic carbon content. (iv) Nitrogen substitution with FYM/GM recorded lower grain yield than 100% NPKZnS but resulted in higher organic carbon content in the soil.

Table 1. Effect of Integrated use of organics and inorganics on grain yield (kg ha^{-1}) under rice – rice cropping system in Godavari Western Delta (32 years mean data)

Treatment	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
	Grain yield (kg ha^{-1})		CoC	CoC	BC ratio	BC ratio
Control	2985^{a}	2135^{a}	76020	99055	0.86	0.47
100% NPKZnS	5117^{c}	5632^{d}	85545	118105	1.32	1.05
100% NPKZnS + FYM @ 5 t ha^{-1}	5532^{c}	6000^{d}	93595	126155	1.30	1.05
50% NPKZnS	4168^{b}	4227^{b}	80782	108580	1.17	0.86
50% NPKZnS + 50% N- FYM	4658^{b}	4935^{bc}	88832	116630	1.15	0.93
FYM @ 10 t ha^{-1}	4449^{b}	3776^{b}	92120	115155	1.06	0.72

1. Development of Production Technologies for Organic Rice Farming

Development of organic package in rice started in year 2008 at RARS, Maruteru under RKVY Programme. Thirteen years of research (2008-2021) results on organic farming was found promising.

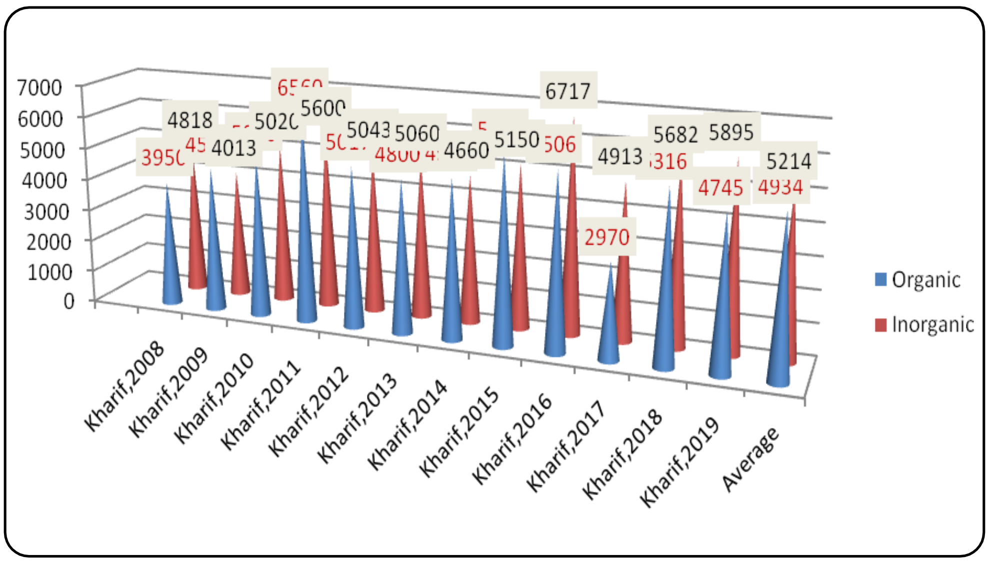
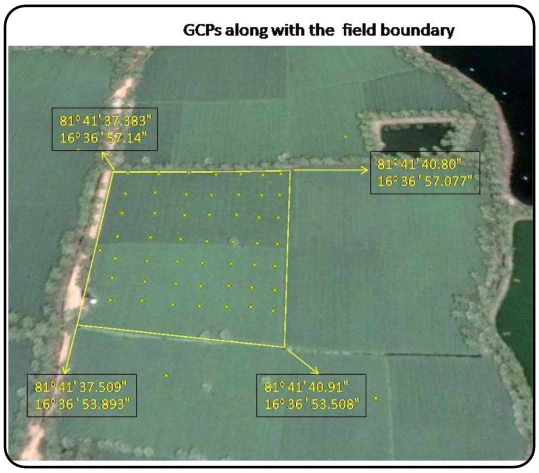


Fig. 2. Comparative Performance of Organic Farming with Inorganic Fertilization

Organic nutrient management recorded similar yields as that of inorganic fertilization treatment during *kharif* season with following nutrient package. (i) Raising green manure crop (Dhiancha) with a seed rate of 15 kg per acre and *insitu* incorporation at 50% flowering stage before transplanting, (ii) Basal application of Farm Yard Manure (FYM) @ 4 t acre^{-1}, (iii) Bio fertiliser application (*Azotobacter* / *Azospirillum* and PSB) @ 2 kg acre^{-1} each, along with 100 kg FYM at the time of planting, (iii) Neem cake or vermicompost @ 200 kg acre^{-1} at tillering and PI stage.

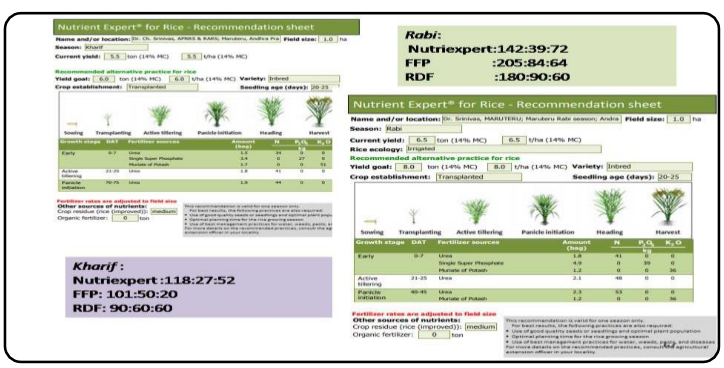
2. Precision Nutrient Management using Remote Sensing & GIS tools:

Precision nutrient management studies were done in small farmers holdings in Batlamagatur village, Penumantra Mandal, West Godavari district of Andhra Pradesh, India. Where, fields is divided into 14 x 14 m grid using GIS tools, soil samples were collected in each grind and Krigged fertility map were prepared for N, P, K, S, Zn, Cu, Fe, Mn and B. Site Specific nutrient management was done in each grid based on the STCR equations. Resulted in higher grain yield (9.8 t ha^{-1}) , straw yields (11.2 t ha^{-1}) and higher BC ratio (3.21:1) compared to blanket application of recommended dose of fertilizers (8.6 t ha^{-1} grain yield , 10.4 t ha^{-1} straw yield and 2.95:1 BC ratio.



Site specific nutrient management through Nutriexpert in rice:

Site specific nutrient management technique (SSNM) is an approach for "feeding" crops with nutrients as and when needed and thus can improve NUE, crop yield and farmers' income. It advocates the optimal use of existing indigenous nutrient sources and timely application of fertilizers at optimal rates. For more rapid adoption of SSNM technology by farmers, efforts were made in the consolidation of SSNM research conducted over the last decade across Asia into a simple delivery system by International Plant Nutrition Institute (IPNI) in the form of NutriExpert (NE). Nutriexpert is a simple computer based decision support system (DSS) or delivery tool that can rapidly provide nutrient recommendations for N, P and K for crops for individual farmer's fields in presence or absence of soil testing results. Application of fertilizers based on the Nutriexpert was (118-27-52) higher nitrogen, lower phosphorus and potassium than the recommended dose of fertilizers (90-60-60) during *kharif* season for rice and lower nitrogen and phosphorus and higher potassium (142:39:72) during *rabi* (180:90:60).



3. Molecular Characterization and Phenotypic Validation of Rice Genotypes for Nutrient Use Efficiency :

Enhancement of rice productivity with low inputs not only reduces cost of cultivation but also improves soil and human health. Nitrogen and phosphorous are important macro nutrients of chemical fertilizers. Breeding of nutrient use efficient genotypes is complex influenced by soil and environmental parameters .Use of molecular markers is one of the best strategies for breeding programmes and selection of high yielding nutrient use efficient genotypes. At, RARS, Maruteru 350 rice genotypes were screened using Nitrogen use efficiency (NUE) and Phosphorous uptake (Pup1) QTL linked markers. Allelic variation in expression of positive e alleles for both Nitrogen and phosphorous use efficiency was observed. Only 13.14% of genotypes (Swarna, MTU 1061, Swarna ub1, Non-abokara, MTU 1229, MTU 1190, MTU 1226) were identified as nutrient use efficient for both Nitrogen and Phosphorous after molecular characterization and phenotypic validation. The future research has to be focused on breeding nutrient use efficient genotypes by novel approaches.

4. Controlled Nitrogen Fertilization with Use of Leaf Colour Chart:

Leaf colour charts of International Rice Research Institute, Philippines and Indian Institute of Rice Research, Hyderabad are tested at regional Agricultural Research Station, Maruteru and found promising and N fertilizer saving was observed to the tune of 15-20%.

5. Field Monitoring of Green Houses Gases from a rice-rice cropping system using portable CO_2 Analyser

The CO_2 fluxes from the rice field from the test variety MTU-1010 by using portable CO_2 Analyser were measured during *rabi*, 2010-2011 of long term trial on soil fertility management under rice-rice cropping system. The CO_2 fluxes were determined from the above five treatments under flooded conditions. The details of treatments are Control, Inorganic N (180 kg ha^{-1} (*Rabi*), Inorganic NPK (180:90:60 kg/ha), FYM @ 10 Mg ha^{-1} and Inorganic NPK (180:90:60 ha^{-1}) and FYM @ 5 Mg ha^{-1}. Carbon dioxide fluxes were measured at five stages *viz.*, transplanting, maximum tillering, panicle initiation and maturity. The CO_2 fluxes were recorded both at morning and evening 3-4 PM to find out the diurnal variation. CO_2 fluxes in the morning at 9 AM varied from 0.12 to 0.69 g CO_2 m^{-2} hr^{-1} while in the evening at 3 PM it varied from 0.26 to 0.76 g CO_2 m^{-2} hr^{-1}. Carbon dioxide fluxes increased upto panicle initiation stage of rice crop and decrease there after upto maturity. Among the treatments, Inorganic NPK (180:90:60 ha^{-1}) and FYM @ 5 Mg ha^{-1} recorded significantly higher CO_2 fluxes compared to other treatments in the study (Fig.). It was noticed that evening CO_2 fluxes were significantly more than morning fluxes irrespective of the stage of crop growth. The average CO_2 fluxes upto panicle initiation stage were 12% more in the evening than morning where as the inorganic and organic treatments recorded 7% higher CO_2 fluxes in evening period than morning.

6. Carbon Sequestration studies using Eddy covariance system:

Tropical low land flooded rice is a unique ecosystem in term its gaseous exchange and energy partitioning, thus plays a crucial role in the global budget of greenhouse gases. Thus, an Eddy covariance system along with the different bio - meteorological sensor were established at Regional Agricultural Research Station, Maruteru, West Godavari to measure net CO_2 /H_2O fluxes from flooded rice ecosystem.

Net Ecosystem CO_2 Exchange (NEE) was gap filled and partitioned into Ecosystem respiration (RE) and Gross Primary Productivity (GPP) using R-eddyPro. The mean NEE varied from +4.33 to –12.58 μ mol CO_2 m^{-2} s^{-1}. The rice paddy ecosystem was behaving as a CO_2 source during night hours and a CO_2 sink during the day.

7. Sustaining crop productivity in coastal problematic soils

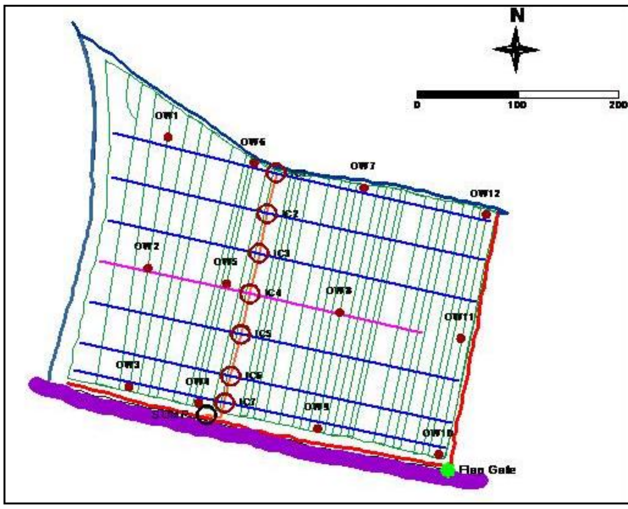
In spite of extensive studies on the effects of salinity on rice, our understanding of the quantitative effects of salinity on rice yield and the critical thresholds of responses with respect to modern, commonly used cultivars of India is still limited. Studies were conducted to determine the effects of soil salinity and depth of soil (0–15 cm and 15–30 cm) on *kharif* and *rabi* rice yields in Godavari delta.

Regression equations and critical soil salinity thresholds for yield reduction in the rice-rice cropping system.

Season	Soil depth (cm)	Equation	Predicted threshold ECe (dS m^{-1})	
			10% yield loss	25% yield loss
Rabi	Surface (0–15 cm)	Y = –0.16x + 7.74	10.9	17.1
Rabi	Subsurface (15–30 cm)	Y = –0.15x + 7.72	11.5	18.1
Kharif	Surface (0–15 cm)	Y = –0.37x + 6.15	5.0	6.9
Kharif	Subsurface (15–30 cm)	Y = –0.17x + 5.68	8.2	12.4

Parallel composite type of subsurface drainage system with a later distance of 50 m was found effective in reclaiming salinity and water logging problem in Godavari delta.

Composite type of layout was selected to suit the topography of the pilot area. On western side of collector pipe, 7 laterals of about 225 m were installed and on eastern side 7 laterals of about 275 m length were installed at a spacing of 50 m. (Figure given below).



Type of system	Single collector parallel grid system
Drain spacing	50 m
Drain depth	0.8 m
Slope of the Collector line	0.0003
Slope of field drains	0.001
Envelope	Nylon mesh
Pipe material	
For laterals	Corrugated PVC (80mm diameter)
For collector	Rigid PVC (160 mm diameter)
Design discharge	1 mm/day

Remote Sensing and GIS based Decision Rules for Aquapond Monitoring (A case study : Guntur district, Andhra Pradesh)

Prasuna Rani P., Sunil Kumar M and Geetha Sireesha P.V.

Saline Water Scheme, Bapatla
Acharya N.G. Ranga Agricultural University

All along the coastline of Andhra Pradesh, prime quality rice fields have been converted to aquaculture being a highly remunerative source and allured by few success stories. The degradation of soil quality by the surrounding aquaponds enforced several farmers to shift to aquaculture. However, due to lack of sufficient technical know-how, huge investments and frequent disease incidence, several aquaponds were abandoned. In Kalipatnam pilot area of Undi Network Centre, ANGRAU, lands affected by salt water intrusion were converted into aquaculture, but the ponds were abandoned as it was no longer profitable due to input costs and disease incidence (APWAM, 2008). Heavy losses were incurred by aqua farmers due to failure of crops. There by farmers were forced to abandon aquaculture and shift to Agriculture. Since considerable extent of aquaponds were abandoned in some of the mandals, it is essential to map the spatial distribution of seasonal variation in used ponds and abandoned aquaponds.

This called for the attention of the scientific research to identify and map the temporal variation in usage and spatial distribution of deserted aquaponds for bringing them to normalcy after following necessary reclamation measures. The study was carried out to develop methodology for monitoring the usage of aqua ponds in Guntur district, Andhra Pradesh a typical representation of coastal ecosystem of the state for generating seasonal spatial aquapond usage maps and abandoned aquapond map considering the aquaponds kept empty throughout the study period. The geospatial tools like remote sensing for detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation and GIS for manipulation of data and generation of spatial distribution maps of earth features play key role in resource monitoring. Landsat-TM, SPOT-MLA and Indian Remote Sensing satellite (IRS-1C), Linear Imaging Self-scanning Sensor (LISS-III) digital data were used to delineate and monitor temporal changes in the spatial extent and distribution pattern of aquaculture. Besides, IRS-1C LISS-III and PAN-merged digital data were used to study details within the areas where, aquaculture is practiced (Dwivedi and Sreenivas, 2005).

The used and empty aquaponds were demarcated with Landsat satellite (Landsat-8) Operational Land Imager's (OLI) multispectral image using maximum likelyhood classifier (MLC) algorithm and spectral indices. Townshend and Justice (1986) used the spectral indices like Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Modified NDWI (MNDWI), Water Ratio Index (WRI) and Automated Water Extraction Index (AWEInsh) to enhance the discrepancy between water bodies and land. Combination of spectral indices was used for surface water estimation, by Acharya *et al*. (2018) to separate water from the background considering threshold values.

The overall methodology followed for the study considering the Landsat 8 data of 2017, 2018 and 2019 is depicted in Figure 1.

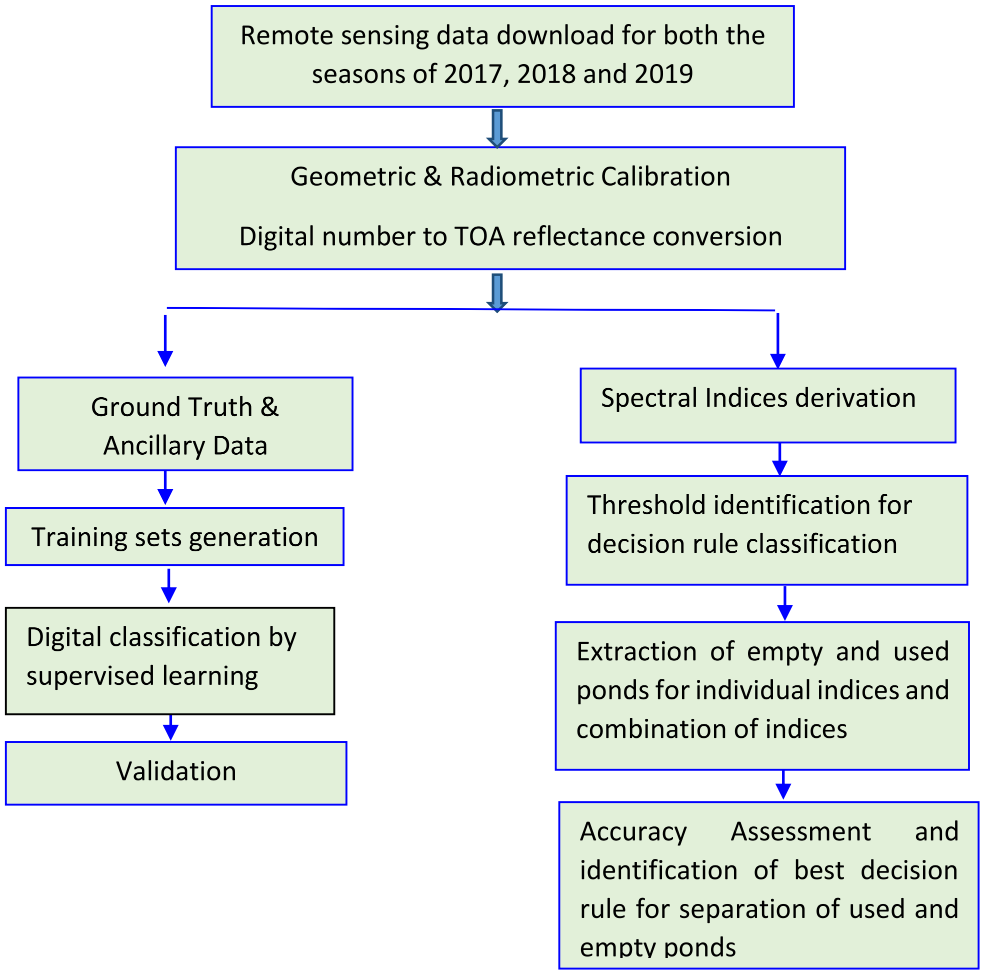


Fig. 1. Methodology for identification of suitable decision rule

Initially, Landsat 8 optical data of different periods were downloaded, rectified and colour composites were developed. The satellite data best representing the used ponds in both the seasons (March-May and October to December) of 2017, 2018 and 2019 were downloaded and the *digital numbers* (*DN values*) of the satellite data were converted to top of atmosphere (TOA) reflectance values with the help of spatial modeler in ERDAS imagine.

The supervised classification was carried out for Area of Interest (AOI) by developing a training set and using maximum likelihood algorithm. The image classified by supervised classification for identification of used and empty ponds was evaluated through accuracy assessment in ERDAS Imagine software considering the ground observations, high resolution satellite data, local and expert knowledge.The error matrices indicated that aquaponds were classified well, whereas the low producer accuracy for empty ponds and relatively lower user accuracy and kappa index for others indicated the misclassification of some pixels demonstrating slight agreement with reference data and marginal suitability of the method.

Further, various indices *viz*., Normalized Difference Water Index (NDWI), Normalized Difference Vegetation Index (NDVI), Modified Normalized Difference Index (MNDWI-2)and Water ratio index were calculated using the formulae presented below.

NDVI	**= (NIR−Red)/(NIR + Red)**	**(Kriegler *et al.*, 1969)**
NDWI	**= (Green−NIR)/(Green + NIR)**	**(McFeeters, 1996)**
MNDWI-2	**= (Green−SWIR2)/(Green + SWIR2)**	**(Xu,2006)**
WRI	**= Green + Red / NIR+SWIR1**	**(Shen and Li, 2010).**

The derived products indicated that that used aquaponds recorded positive values for MNDWI and NDWI while, negative values for NDVI. Abandoned ponds and vegetation recorded vice versa. The indices derived were used to identify the used aquaponds, empty ponds and other land uses in the area of interest individually and in combination. To achieve this, threshold values for the indices were decided by means of validation points using visual interpretation of satellite data, ground observations, Google earth explorer, expert knowledge, *etc*.

Decision trees (Fig. 2 &3) were built in ENVI software for decision classification of land uses using threshold values for different indices individually and in combination.

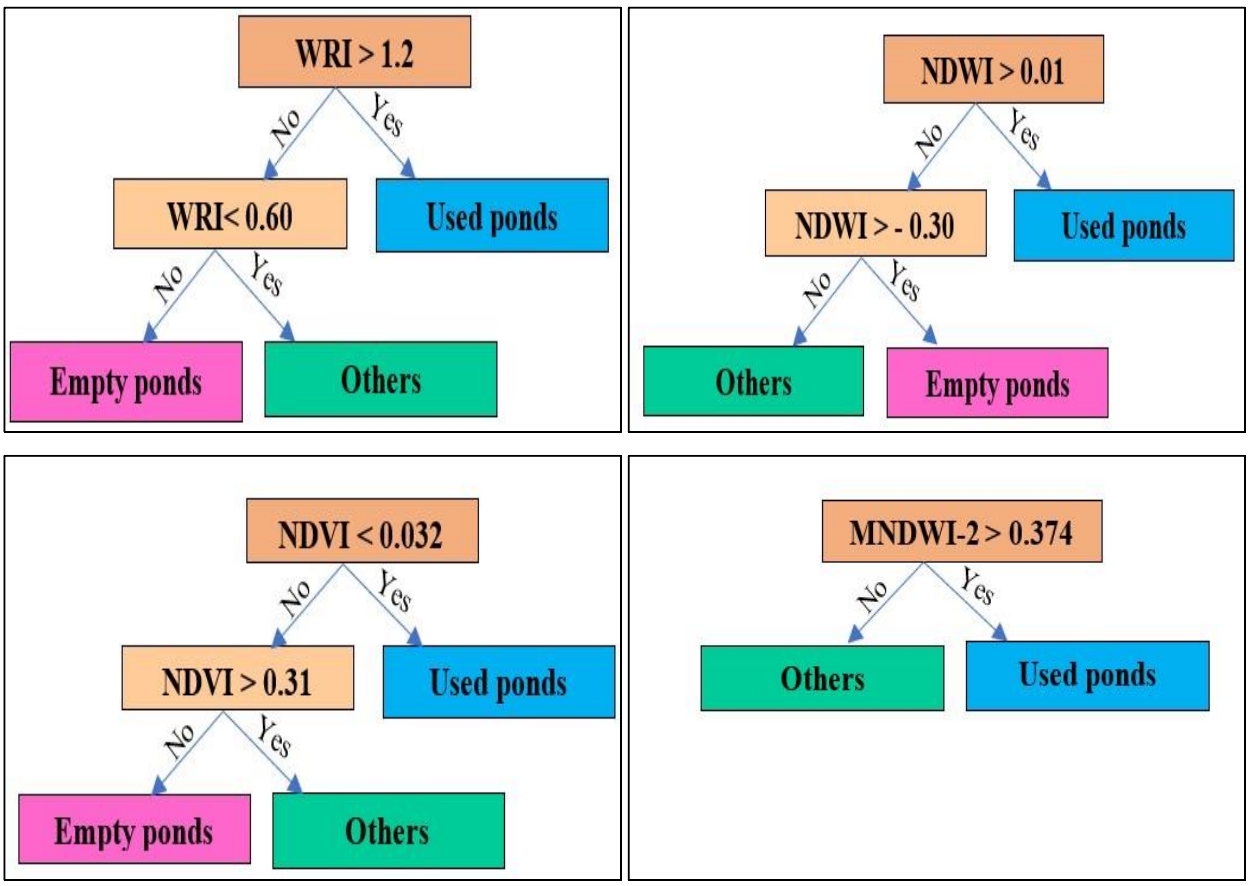


Fig. 2. Decision trees used for land use classification of AOI for individual indices

The indices *viz*., NDVI, NDWIand WRI were found useful in differentiating all three classes *i.e*. used aquaponds, empty ponds and other land uses. Only two classes (used and empty aquaponds) could be separated by MNDWI-2 while, other features could not be separated properly.

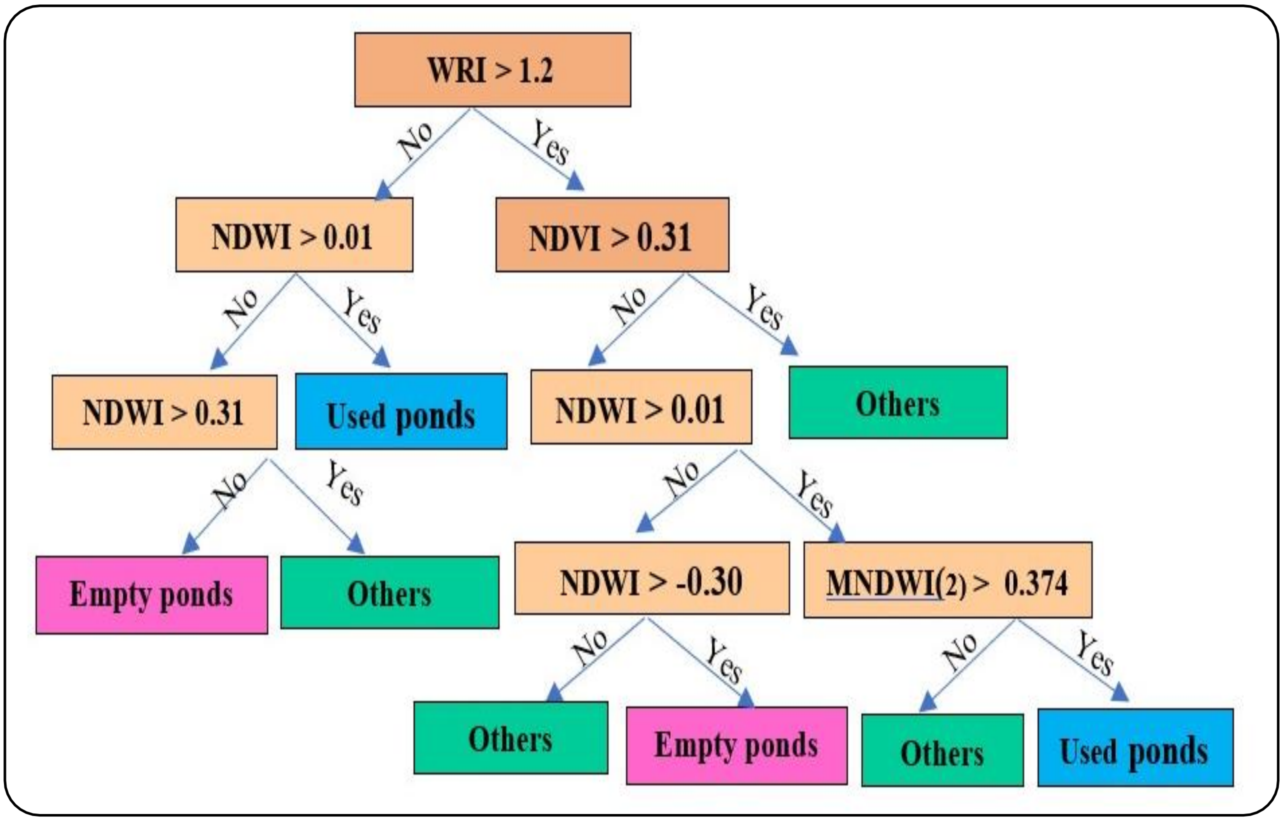


Fig. 3. Decision trees used for land use classification of AOI for individual indices
(Source: Prasuna Rani *et al.*, 2021)

The NDWI, among the individual indices resulted in mean highest overall accuracy (91.8%) and kappa coefficient (0.87) values for all the seasons, showing a strong agreement with reference data while, NDVI recorded the lowest. The mean highest overall accuracy of 95.5 per cent and 0.93 were attained for decision rule with combination of indices indicating perfect agreement with reference data. Hence the used ponds and empty ponds in each season were extracted using the decision rule with combination of indices (WRI, NDWI, NDVI and MNDWI-2). Further, the extents of aquaponds commonly left empty in both the seasons of each year and during all the seasons were derived by overlay analysis in QGIS.

The methodology developed using remote sensing and GIS can be extended with threshold checking to other coastal regions for regular monitoring of used aquaponds and identify abandoned regions for better management.

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Farm Mechanization - Special Emphasis on Coastal Ecosystem

C. Ramana and K. Madhusudhan Reddy

Regional Agricultural Research Station, Tirupati – 517 502
Acharya N.G. Ranga Agricultural University

India being a very important agriculture dependent country and farmers are entrepreneurial in adopting new varieties and latest technologies. country's population touching 140 crores, but due to acute shortage of agricultural workforce and sudden drop in animal force in farming, moreover changing life style of rural youth (not inclined to work with agriculture) making farmer to renounce the agriculture. Moreover changed agricultural scenario age old incompatible machinery is neither meeting the demands of high production technologies nor able to complete the agricultural operation in time. To combat with new tasks of production technologies in handling more yields is possible only through mechanization Moreover improved Farm mechanization technologies will not only, reduces the cost of cultivation but also to bring significant improvement in productivity. Farm mechanization can improve operational comfort and rural house income with minimum risk i.e., timely completion of operations and improved productivity in agriculture and infuses better working environment there by Social Status**.**

The neglected popularization of operation specific or area specific machinery caused dent in usage of correct machinery in Indian farms. Some of farmers still under the impression that tractor with trailer / cultivator is whole about farm mechanization. Hence it is dire essential to have orientation on operation specific machinery to solve the problem of dearth of energy.

Primary tillage

Any crop requires better tilth and congenial environment to extend roots proliferate crop, but majority of farmers till the land with cultivator irrespective of crop grown and some of the farmers do with rotovator which are basically secondary/intercultural equipment. The operation by these equipment cannot break open hard-pan (consolidated soil mass formed due to weathering and machinery movement) crop grown under such environment will restrict its growth to the extent of loose soil. Hence primary tillage is dire essential in crop production system. To break open the consolidated soil up to the depth of 30-45 cm and to provide soft, friable soil base for progress of plant growth use of primary tillage implements is essential. Since soils of coastal eco-system usually consist of sandy soils, loamy sands sandy loams, which also require good tillage practices to support the crop.

Mould Board Plough is useful in preparing field up to 45 cm, turned and pulverized. The MB plough enters in to the soil due to suctions in configuration and is 300% efficient when compared to Bullock drawn country plough or cultivator. The implement can efficiently be used in stone free, non sticky soils. To avoid undulations in the field, two way reversible Mould board ploughs are available which can be operated with hydraulic shift lever.

Disc Plough: In stony stumpy sandy soils, Disc plough can be successfully administered. This plough has got rolling plough bottom, hence it is useful for any type of soils and plough enters in to the soil due to self weight of the implement. If required, dead weights can be added to the implement for more depth up to 45 cm even in dry soils. The rolling discs orientation like disc angle and tilt angle be changed for getting better quality soil tilt.

Mould board plough

Disc Plough

The research results on root development studies infers that crop can extend its roots up to 2.1 m (Sudhakar *et.al*., 2010) under favorable root environment system. Hence to provide favorable root growth environment the field must be prepared to the possible depth. This not only envisages better root growth but also aids in in-situ moisture conservation. Similarly studies on the effect of primary tillage (MB plough and rotovator) on groundnut growth parameters revealed that there is an increase of 14.5 per cent yield growth over farmers' practice i.e., cultivator and rotovator used for preparatory cultivation (Ramana.C 2015). Moreover, depth of cut and disturbance of soil will provide better exposure to nutrients and moisture therein productivity enhancement is made easy.

Sub Soiler: Sub soiling i.e., cutting soil strata up to the depth of 40-75 cm on the field, makes vertical cut and administered once in three years to manipulate lower layers of soil strata and aids in adding new soil with old soil on top layers. But the sub soiling (vertical tillage) is also creates vertical trough for entry of rain water received in that field and lateral movement of excess water as runoff is restricted. The entry of rain water in deep layers through vertical cuts will moist soil below surface and be intact (as reservoir) without getting evaporated. Moisture below surface layers help crop to sustain even in long periods of dry spell and insures the crop. This phenomenon of entry of rain water in to the deep layers minimizes surface runoff, thereby minimizing transportation of fertile top-soil, remains in the same field (protecting soil against erosion). Deep layer tilling through sub-soiling also envisages the plant to develop deep roots and accessed to preserved moisture and more volume of soil nutrients. Experiment results also shown that there is less disease (collar root rot) instance, even in prolonged dry spell with sudden down pour (precipitation) recorded in sub-soiled field, but whereas complete damage due to collar root rot in un-treated fields (shallow ploughing was done) of groundnut, this is mainly due to moisture presence in the field soil where Sub-soiling is administered (Ramana, 2014).

Hence usage of primary tillage during summer not only improves the productivity but also reduces pest and disease complex, field preparation with primary tillage implements can improve production of up to 12% in the rain fed and 15-18% in irrigated dry crop situation.

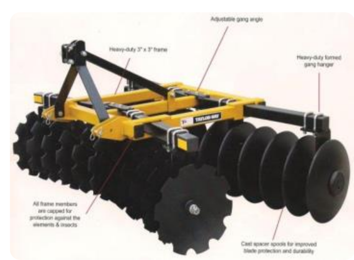
Secondary tillage:

Act of primary tillage, ploughing to a depth of 45 cm will cut, invert and to some extent pulverizes soil, which handles more mass of soil and makes the field undulating (with soil clods). The cloddy and undulating conditions is not congenial for sowing process, since even soil contact with seeds could not be established germination initiated in the undulating field conditions. Hence to make the field ready for seed bed (soil) need to be further processed/pulverized and requires a special type implements like disc harrow, spike toothed harrow, blade harrow etc.

Rotovator: this is an active implement and gets the power from PTO shaft of the tractor and rotates horizontally mounted central shaft on which soil working tynes are mounted and cuts the soils clods. The action of Rotovator on the already ploughed land makes friable and soft. This action of pulverizing soil automatically fills pores with air (pockets) in to the soil system and be useful for plant & root growth. Since the Rotovator consists of door in the rear to adjust clod size of the soil in the operation and it also helpful in making field level and clod free.

Power Hoe: This is an active tool and gets the power from the tractor PTO to rotate the vertically (independently) mounted tynes in the housing. These tynes are made of high carbon steel and sharpened to generate cutting action on the soil. The rotation of the tynes makes clods in to friable soil. Since the tynes are located vertically the bottom portion of the field will not become hard and puffing action is created. The soil will become more of air pockets and be very useful for root crops like groundnut, potato, onion etc.

The implement is also useful for churning and mixing up of the soil. The rotary hoe also will have door in the rear to make the field level one and be immediately used as seed bed for the crops. The power hoe can complete 0.75-1 acre/hour.



Disc harrow: disc harrow consists of rotating discs as soil working components, it is a passive tool. The implement will have number of gangs on which number of discs mounted with spool and scraper so as to mix the soil thoroughly. The numbers of gangs are 2 or 4 and a disc on the gang varies from 6-18 depending on the size of the equipment. The gangs are provided with two different discs usually in front gang notched type discs and plain discs in rear gang. These discs are mounted on square centered shaft and with some disc, angle (20-23°) to the line of travel. The arrangement inculcates the rotation when the implement dragged with tractor. The rotation of discs will crush the clods and mixes with two opposite disc gang arrangements. The capacity of the implement depends on number of gangs and discs per gang. Normally it can cover 1 ac/hr.

Spike tooth harrow: this harrow is used for clod crushing and combing up operation after primary tillage operation. This is a passive implement and does good mixing and crushing with mounted tynes. Some of the spike tooth harrow are mounted with spring tynes which can enter to better depths than ordinary tynes. This tynes are mounted on frame, this implement is better used for cleaning of crop & weed residues from the fields.

Blade harrow: this is a passive tool and being attached with 3 point linkage system of tractor as integral part. This is used after primary tillage and at the end of secondary tillage operation Blade harrow is fixed with a single blade or double blades to the vertical drops (standards) of frame. Frame consists of the provision to mount on a tractor as a mounted implement. The blade of the implement will cut undulating soil portions beneath the ploughed (or) tilled soil. The scraping of these undulating soil lumps will greatly help in uniform irrigation in entire field and avoid dry patches of crop in the field. The cutting of hidden bumps under soil is very much essential and saves irrigation water up to 10% and provides uniform crop growth & maturity which improves water productivity.

Equipment suitable for rice cultivation:

Rice is grown under wet as well as dry conditions, in this process for wet land preparation is puddling, it is done with the help of roto-puddler

Vishnu Puddler

Vishnu Puddler (self activated passive tool) was developed for doing puddling so as to save irrigation water up to 40 per cent over farmers practice of using cage wheels with cultivators in low land transplanted rice system. Since it is passive tool the consumption of fuel for operation is saved by 2 litres/h when compared with rotovator puddling for same effect of formation of semi impervious layer.

Roto Puddler

It was developed for Land preparation (Puddling). It is the perfect solution for wet land application. It has been specifically designed for preparing the seedbed for transplanting rice. Depth of puddling will be 17.2 to 19.0 cm with a puddling index of 75.0 to 79.5%.

Seed treatment equipment

Seed treatment drum: seed treatment drum is used for thorough mixing of pesticides with groundnut seed before sowing as a plant protection measure. It consists of a drum mounted on a frame at 40^0 with horizontal and operated manually by using a crank handle. It saves 33% labour, operating time and cost of operation over conventional method of mixing manually with land. Its overall dimensions are 900 X 700 X 400 mm and weigh about 25 kg. The drum capacity and mixing capacity are 10 kg and 100 kg/h respectively with mixing efficiency up to 90%.

Sowing Equipment

Majorly in coastal ecosystem rice as well as groundnut is grown for which the implements like transplanters, drum seeder and seed drills etc., are being used

Transplanter

It is a six-row rice transplanter using mat type seedlings. The four row machine is a riding type and employs a double acting transplanting mechanism for enhanced transplanting speed and in turn high field capacity. The double acting transplanting mechanism is run with, one sun and four planetary gears. The row-to-row spacing is 300 mm and five setting of hill-to-hill distance from 120 to 220 mm can be fixed depending on desired plant population. The machine is provided with six spare seedling racks for filling of trays intermittently. The machine is powered with a 12 hp air cool petrol engine and it is provided with power steering. .Depth of transplanting can be set from 15 to 45 mm.

Drum Seeder

Drum seeding technique involves direct seeding of pre-germinated paddy seeds in drums made up of fibre material to dispense seeds evenly in lines spaced at 20 cm apart in puddled and levelled fields. About 35 to 40 kg paddy seed/ha is soaked overnight in water and allowed to sprout. Duration of the crop can shortened by 7-10 days compared to traditional practice.

Sowing equipment: Sowing is a very important operation which has to be performed timely especially in irrigated dry and rain-fed cultivation. The sowing also very important for making complete mechanization like intercultural operation, spraying and harvesting. Since the groundnut kernels are very soft and care need to be taken (not to crush damaged) during sowing. The seed rate also needs to be accurate for maintaining groundnut productivity.

Sathi bullock drawn groundnut planter

To mechanize the sowing operation by using bullock drawn groundnut planter was designed and developed at Agricultural Research Station, ANGRAU, Ananthapur. It is provided with a trough type seed metering mechanism for seed placement in the row. This covers four rows at a time with row to row distance of 30 cm and maintains seed to seed distance of 10 cm in a row at 4-5 cm depth of sowing. The recommended seed rate i.e. 100 Kg/ha can be maintained. It can also be used for other crops like Bengal gram, castor and red gram by changing the row to row spacing and disc in seed metering mechanism. The field capacity is in between 1.5 to 2 ha/day. The capacity of hopper is 8 kg for groundnut.

Seed cum fertilizer drill (Gujarat model):

This seed cum fertilizer is provided with seed and fertilizer boxes along with seed metering mechanism (trough feed) and mounted on 9 tynes cultivator (Rigid and spring tyned optional based on soil type). The depth control system was provided to maintain uniform depth through two guage wheels. The row spacing of the sowing can be adjusted as per the season/requirement. The covering device is placed behind the implement to close the furrows immediately after sowing (with rear plank). Similarly the same seed drill can be used for any type of seed sowing for which seed metering scoop wheels need to be changed. Fertilizer drilling qualities also can be monitored by changing sliding door at the bottom of fertilizer box and beginning of the fertilizer spout.

Tractor drawn Anantha groundnut seed cum ferti drill

Tractor drawn groundnut seed cum ferti drill –row tractor operated groundnut seed drill with row to row spacing of 30 cm fir timely sowing with mechanical advantage and intercropping fertilizer facility is provided. This is provided with a hopper and seed metering mechanism as the main components. The hopper is divided into boxes each can accommodate 5 kg of seed (total 40 kg). the inclined plate seed metering mechanism gives correct seed to seed distance of 10 cm in a row and maintains the recommended seed rate of 100 kg/ha with optimum plant population of 33 per square meter area. Placement of seed is at proper depth of 4-5 cm. the seed damage is negligible and the field capacity is 6 to 7 ha/day and facilitates coverage of large area before the soil moisture is dried up. A 5 cm width covering blade is also attached behind the furrow openers to cover the furrows opened after seed placement. The intercropping of redgram or castor can also be possible using Anantha planter along with groundnut sowing. The spring type cultivator frame of this planter facilitates to work even in stony soils. The cost of Anantha planter is approx. Rs. 55,000.

Intercultivation equipment

Bullock drawn inter-cultivation implement: It is a 4 row bullock drawn inter-culture implement used for removal of shallow depth weeds in between rows of groundnut crop. It consists of 4 straight blades, frame, handle and beam to attach with a pair of bullocks. The blades are fixed to the frame to which handle is attached. The blades are the working components which are made from medium carbon steel or mild steel for more strength to resist soil friction and to have long life. The width of each blade is 15 cm. for operation, the weeder is passed in between the rows of crop so the blades cut and uproot the weeds. Its field capacity is 2.0 ha/day.

Bullock drawn intercultivation equipment

Tractor drawn inter-cultivation implement: This is a 8 row tractor operated inter-culture implement used for weeding in groundnut crop developed at Agricultural Research Station, ANGRAU, Ananthapur. Its frame is provided with 8 tynes each tyne attached with T or V-shape sweeps to work in between 30 cm row spacing of the crop without any plant damage. Two small width pneumatic tyres of 8.3 X 28 "size need to be fitted to the rear axle of the tractor to run in between rows of the crop instead of normal size tyres to prevent trampling of plants under the tyres. The size of the seeps range from 4" to 6 ". The cost of inter-culture implement and pneumatic tyres with sweeps is approx. Rs.45, 000. Its field capacity is 4 to 5 ha/day.

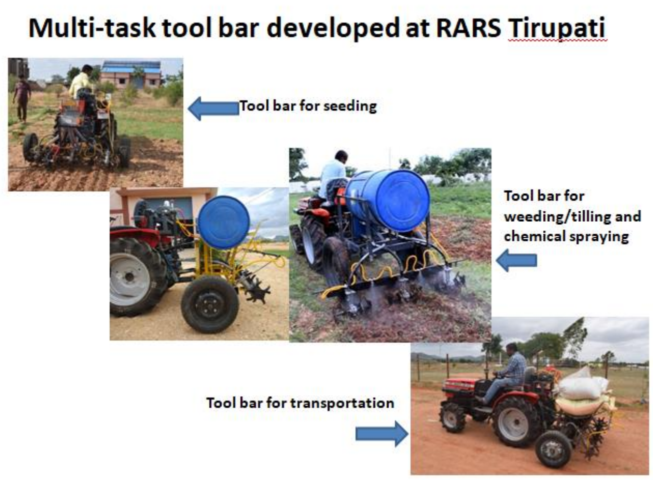
Tractor drawn inter-cultivation implement

Boom Sprayer

Boom Sprayer: it is a sprayer with larger width of operation and covers more area in a lesser compared to power sprayers. It consists of a pump, one plastic or fiber glass made tank of 400 litres capacity, control valves, relief valve and a spray boom fitted with nozzles. The pump is operated by the PTO shaft of the tractor at the high pressure of around 20-55 kg/cm^2. The complete sprayer is mounted on 3-point linkage of the tractor. The boom may be of flexible hose pipe on which nozzles are mounted to meet crop row spacing. The bottom is fixed with a rigid beam by clamps. Inlet liquid supply to boom is provided at two points for even distribution of liquid. Hole are provided on the frame to lower or raise the beam to adjust the height of spray. This boom has 13-15 triple action nozzles and can cover 7-8 m width. Two small width pneumatic tyres of 8.3"X28" size need to be fitted to the rear axle of the tractor to run in between rows of the crop instead of normal size tyres to prevent trampling of plants. Its field capacity is 8 ha/day at the operating speed of 3.5 km/hr. application rate is 400 L/ha and initial cost about 1,10,000.

Multi Task Tool Bar:

The "Tractor drawn Multi Task Tool bar" was developed for small farmer of India (under Externally funded ICAR Extramural project) The machine can be used for sowing, intercultural operation and for chemical spraying. The equipment can be successfully used in field crops like groundnut, green gram etc. In addition to these said operations the machine can be used as cart during off season. The machine can be operated even by small statured tractors. The cost of the Machine was kept below 1.0 Lakh



Harvesting equipment

Reaper cum binder

It is suitable for harvesting and making bundle of wheat, paddy and other oilseeds and pulse crops. It is operated by 9 kW diesel engines. The riding type self–propelled vertical conveyor reaper windrower is powered by a 9 kW, single cylinder, water cooled diesel engine having rated engine speed of 3000 rpm. The harvesting system include crop row dividers, star wheels, standard cutter bar having 76.2 mm pitch of knife section, vertical conveyor belts and wire springs. The effective cutter bar width is 1.2 m. At the end, the crop is discharged on the ground in the rear. Working capacity of reaper binder is 0.3-0.4 ha/h. Weight of the machine is about 450 kg.

Combine Harvester

Combine harvesting *combines* several operations into one: cutting the crop, feeding it into threshing mechanism, threshing, cleaning, and discharging rain into a bulk wagon or directly into a bags. Straw is usually discharged behind the combine in a windrow. Crops are gathered in by a *header* at the front. Different headers are used for cutting different crops in different landscapes. After passing through the header, the crops are pushed into the *cutter* by a slowly rotating wheel called the *reel* (or pickup reel). The reel has horizontal bats and vertical tines to get a good grip of the crop stalks. The *cutter* bar which runs the entire length of the header is located underneath the reel. Its mowing fingers open and close repeatedly to cut off the crops at their base. The cut crops are moved towards the center of the combine and go up a conveyor to the processing mechanism inside the main part of the combine. A *threshing drum* beats the cut crops to break and shake the grains away from the stalks. Harvesting speed ranged from 2-4 km h^{-1} and actual field capacity ranged from 0.6-0.7 ha h^{-1}.

ANGRAU blade guntaka

ANGRAU blade guntaka designed and developed at Agricultural Research Station, ANGRAU, Anantapur is used for digging of groundnut crop after maturity at the soil moisture range of 8-15%. It is provided with main components frame, 3-point linkage and a straight blade. All the components are made of MS material. The blade is the working component for digging of crop and its length and width are 135 and 8 cm respectively. It has the working width of 135 cm and covers 4-covers 4-5 ha in a day at the recommended speed of operation of 2-3 km/hr. the digging efficiency is 90-95%.

Groundnut digger, shaker cum windrower

It is also used for harvesting of groundnut crop at soil moisture levels of 8-15% and operated with above 45 H.P tractor. It has the working width of 120 cm and covers 4 rows of groundnut crop at row to row spacing of 30 cm. its overall dimensions are 1700 X 1000 X 1050 mm provided with soil loosening tool of sweep type, a pick conveying mechanism and gatherer windrower. The soil engaging tool is made of high strength mild steel. At the rear, a gatherer windrower the conveying crop. While conveying, soil get removed from crop due to shaking action. The field capacity is 0.8-1.0 ha/h at the recommended speed of operation 2-3 km/h. harvesting and soil separation efficiencies are 96 and 95% respectively. Saving in labor cost and time are 50 and 95% respectively compared to manual harvesting. Its cost is about Rs. 1,80,000.

Threshing equipment

Groundnut fresh pod thresher

It is suitable for stripping of groundnut pods from harvested crop and consists of a wire spike type cylinder powered with 2 H.P electric motor. Stripping is done by holding the portion of a bunch manually over spiked cylinder. Three persons can work at a time. It is also provided with a blower and sieve for separation of pods from plant stalk, leaves etc. it saves 40% labour, 50% operating time and 30% cost of operation and it also results in 4% reduction in losses compared to conventional method of stripping. It was developed at ANGRAU, Hyderabad. Output capacity is 120 kg/ha with 100% stripping efficiency and 98% cleaning efficiency.

Groundnut fresh pod stripper

It is a throw-in type thresher used for separating pods from plants immediately after harvesting of groundnut crop. The farmer no needs to wait for drying of crop after harvesting for threshing. It is operated with PTO shaft (Speed 540 RPM) of 35-45 H.P tractors. It consists of frame, feed hopper, drum type threshing cylinder, concave, oscillating sieves and a blower. Total construction sits on the main frame. The threshing cylinder has the diameter and length of 50 c, and 90 cm respectively and working speed of 320 RPM. The cylinder surface is provided with flat pegs arranged in 6 rows such that each row has 7-8 pegs (length of peg 10 cm). A concave is provided under the threshing cylinder for rough separation of pods and stripped plants. An outlet is provided at the rear portion of cylinder for stripped plants. In order to separate all the unwanted material after threshing from the pod, two sieves have been provided below the concave. The top sieve has holes of 50X17 mm size and the bottom sieve has holes of 25X9 mm size. A centrifugal blower with spiral casing has been provided in between the two cleaning sieves for blowing of light weight plant material coming along with threshed pods from the concave. It has the feed rate of 750 Kg/h and output capacity of 300 kg/h with 96% threshing efficiency. It is very useful where the influence of north east monsoon will be more and continuous rains occur at harvesting time. Initial cost is around Rs. 1, 80, 000. It can easily transported from one place to another place as it is provided with pneumatic tyres.

Dry pod thresher

This is also a throw-in type thresher for groundnut crop having moisture content of 15-17% crop harvested needs to be dried before threshing. It is operated either with 10 H.P diesel engine or electric motor. It consists of frame, feed hopper, hammer type threshing cylinder, concave, oscillating sieves and a blower. A concave is provided under the threshing cylinder for rough separation of pods and stripped plants. In order to separate all the unwanted material after threshing from the pod, two sieves have been provided below the concave. A centrifugal blower with spiral casing has been provided in between the two cleaning sieves for blowing of light weight plant material coming along with threshed pods from the concave. It has the feed rate of 500 kg/h and output capacity of 200 kg/h with 95% threshing efficiency. Its initial cost is around Rs.1, 10, 000 including 10 H.P diesel engine.

Decorticating equipment

Hand operated decorticator

Hand operated groundnut decorticator can be used to shell groundnut pods and to separate kernels. It consists of and oscillating sector with sieve bottom and a handle. Number of hard rubber or cat iron lined assemblies are fitted in the oscillating sector unit. The groundnut pods are shelled between the oscillating sector and the fixed perforated concave screen by rubbing action. The decorticated shells and kernels fall down through the perforated concave sieve. The kernel and shells are collected at the bottom of the unit and separated manually. Clearance between the concave and oscillating sector is adjustable to suit the different varieties and concave sieves are also replaceable depending upon the pod size. Its overall dimensions are 600 X 350 X 700 mm. the capacity and efficiency of the unit are 50 kg/ha and 98% respectively.

Power operated groundnut decorticator

It is used to shell groundnut pods and to separate kernels. This is operated with 2 H.P single phase electric motor. It consists of feed hopper, rasp bar cylinder with hard rubber linings, perforated concave screen, tow oscillating sieves and a blower. The groundnut pods are shelled between the rubber linings of cylinder and fixed perforated concave screen by rubbing action. The decorticated shells ad kernels fall down on oscillating sieves through the perforated concave screen. A centrifugal blower with spiral casing provided in between the perforated concave screen and oscillating sieves separates the light weight shells from kernels. Oscillating sieves pods from stalk, leaves and other foreign material. Its capacity is 250-300 kg/h and its cost is around Rs. 40,000 along with electric motor.

Impact of Climate Vagaries on Coastal Agriculture Productivity

T. Prathima and G. Subramanyam

Advanced Agroclimate Research Centre (AACRC), RARS, Tirupati-517 502
Corresponding author: t.prathima@angrau.ac.in

The soil and climate in coastal regions are frequently ideal for Agriculture, a long-standing industry that has played a significant role in coastal regions' economy. In addition to supply of food Agriculture also frequently offers raw materials to coastal inhabitants that have built industries and utilise ports to their fullest potential (Singh *et al* 2020). Due to increased urbanisation, human populations and related economic activities including agriculture, aquaculture, tourism, industries, trades, and transportation in these areas, coastal landscapes are more vulnerable to the effects of disasters (Sekovski *et al.,* 2012, Gari, *et al.,* 2015, Kantamaneni, *et al.,* 2019). Coastal Andhra Pradesh has an area of 95,442 square kilometers which is 57.99% of the total state area and a population of 34,193,868 which is 69.20% of Andhra Pradesh state population (Ojha, 2019) and the coastal line of this region is the second longest in the country, extending up to 1027.58 km (Anonymous, 2018) from Icchapuram in Srikakulam district to Tada in Nellore district. The major rivers are Godavari, Krishna, Tungabhadra, Pennar, Manjira, Nagavali, and Vamsadhara. There is a total of thirteen districts in Andhra Pradesh, four of which are in Rayalaseema region and nine form a part of the coastal region. They are: Srikakulam, Vizianagaram, Visakhapatnam, East Godavari, West Godavari, Krishna, Guntur, Prakasam, S.P.S. Nellore from north to south in geographical order. The coastal AP region accounts for fragile ecosystems of Lagoons, Estuary and Mangroves. In the coastal region, rice is the main crop. Coastal agriculture primarily consists of rice and horticultural crops like coconut plantations, banana and vegetables along with aquaculture. AP is the second highest contributor to fisheries in India.

The effects of climate vagaries have been seen all across the world. Increasing floods, persistent inundation of low-lying coastal areas, increased erosion of beaches and cliffs, depletion of coastal wetlands, and salinization are just a few of the effects that are influencing the world's coastal regions (Burden *et al.,* 2020; Haer *et al.,* 2013; Kumar *et al.,* 2011; Nicholls, *et al.,* 2007). The coastal regions of the world are naturally threatened by climate change vagaries such as cyclones, tidal surges, sea level rise, frequent floods, sudden sedimentation, water erosion, *etc.* because of their geographic location. Many coastal areas have already begun to feel the effects of climate change. In addition, the predicted effects of climate change, such as increased air temperatures, rising sea levels, and an increase in the frequency of extreme weather events (hurricanes, tropical cyclones) would have greater effects on coastal regions, which have low and flat terrain, dense populations, low community awareness of improved livelihood-technologies, and insufficient response as well as preparation for forecasting to combat the harmful effects of extreme events (Bhattacharya *et al*. 2020). India has become the second largest producer in aquaculture, globally after China and contributes to 6.30% of the world's production (FAO, 2014). In general, the number of people engaged in aquaculture and fisheries has increased at a rapid rate than global population increase, and the highest employment levels are found in Asia itself (FAO, 2014). The lower water flows, on the other hand, have a negative impact on the fish habitats and breeding patterns, which affects coastal fisheries. The natural shrimp breeding that typically occurs in the inland coastal waters is impacted by the interactions between the inland and ocean waters (Bhattacharya *et al.* 2020). Overall, it might have an impact on fish habitat accessibility and, consequently, fisheries-water productivity. The damaging, often fatal impacts of water pollution on fisheries in coastal locations are exacerbated by climate change and agrochemical contamination (Haynes and Michalek-Wagner, 2000). Fish spawning grounds and coastal habitats may also be harmed by high sediment loads, silt deposition, and changes in streamflow.

Climate change and coastal agriculture

From 1880 to 2016, the global average surface temperature increased by 0.87°C (IPCC, 2018). More specifically, from 1971 to 2010, the worldwide ocean warmed by 0.11°C every decade, with the greatest warming occurring around the top 75 m of the water (Kumar *et al*., 2012; Heron *et al.*, 2016). The ocean's acidity grew by 26% throughout that time, and the pH of the ocean's surface water decreased by 0.1 scale. From 1979 to 2012, the Arctic sea-ice reserve dropped at a rate of 3.5 to 4.1% every decade, and glaciers have shrunk practically everywhere. Importantly, between 1901 and 2010, the average worldwide sea level increased by 0.19 m. Since the middle of the 19th century, the pace of increase has been faster than the average rate during the previous two millennia (Omondi *et al.*, 2014). The frequency of powerful tropical cyclones has grown over the past few decades, according to a review of extreme events. Additionally, hundreds of fish species have been migrating northward to oceans with cooler water, which is upsetting coastal businesses. Crop production is impacted by the intensity and scope of climate change risk in a number of ways, including crop growth, life cycle, and associated field management. Plant physiological processes and physical damage are affected directly, whereas field operations, environmental factors and coinciding of extreme events with different crop stages have an indirect impact. For instance, higher air temperatures and less precipitation cause drought and heat stress, which have a negative impact on agricultural growth and development (Porter and Semenov, 2005). Additionally, it can make diseases and pests more common (Bale *et al*., 2002). Similar to this, hailstorms, flooding, and strong rains can damage crop canopies physically or by reducing soil oxygen levels, which inhibits plant and root respiration (Kimball, 2008).

Coastal erosion in AP

In a study conducted by Ministry of earth sciences, India a total of 6,632 km long Indian coastline of mainland has been analyzed from 1990 to 2018 and it is noted that about 33.6% of the coastline is under varying degree of erosion. In Andhra Pradesh, 28.7% (294.89 Km) coastline is under varying degrees of erosion (Anonymous, 2022). In Andhrta Pradesh 27% of the coast is eroding, 31% is stable and 42% is accreting. East Godavari and Krishna regions are found to be high erosion prone areas and Visakhapatnam coast is the most stable coast (Anonymous, 2018).

Climate change impacts on coastal crop production

The crop productivity in the coastal region is constrained by nine major climate change-related issues (Fig. 1). The most important of these are high soil and water salinity. The connected issues include the presence of a limited brackish water table, hindered drainage, and a lack of high-quality irrigation water in coastal areas that are periodically inundated by salty sea or ocean water as a result of tidal movement (Bhattacharya *et al.* 2020).

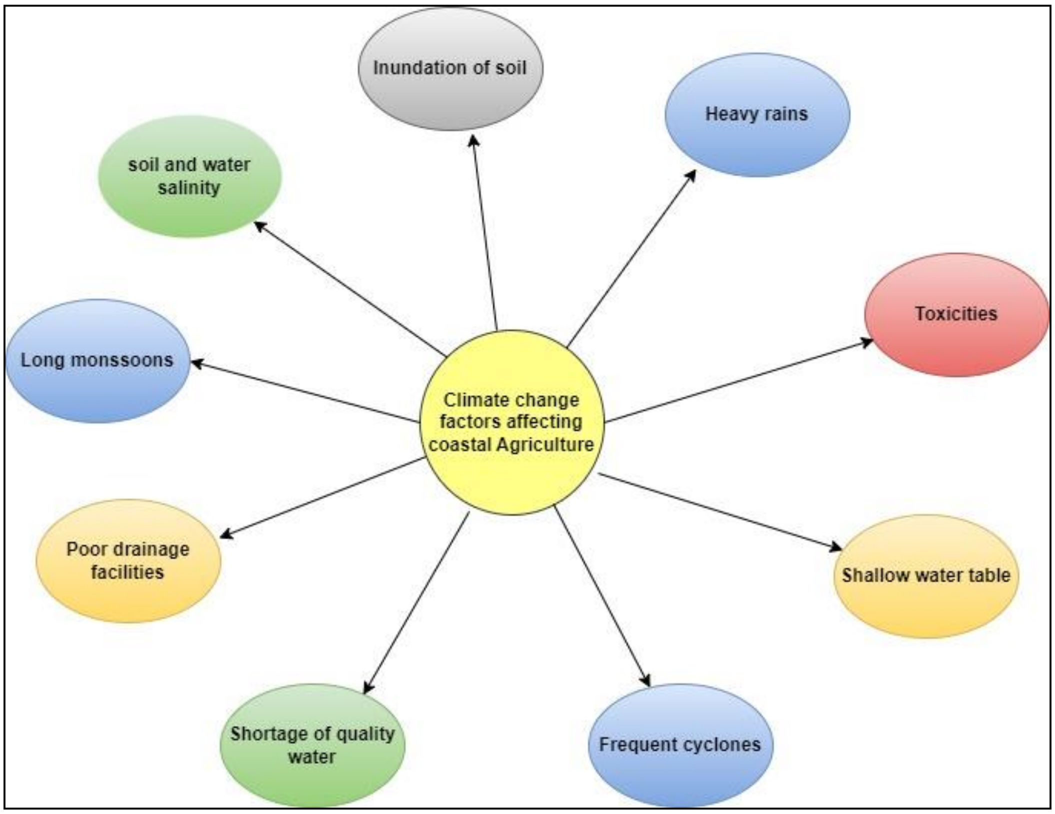


Fig. 1. Climate change factors impacting coastal crop production

Climate trends in coastal Andhra Pradesh

Based on the availability of data, climate trend analysis was carried out in coastal districts of AP. It was observed that, in Visakhapatanam district there is significant increase in maximum temperature and rainfall during the *Kharif* season (Fig 3 & 4). But in case of sunshine hours, there is significant negative trend (Fig. 5). Significant negative trend was observed in minimum temperature of Srikakulam district (Fig. 6) and there is a significant reduction in rainfall during the *Kharif* season (Fig. 7). In Vizianagaram and West Godavari there is a significant increase in maximum temperature (Fig. 8 &10). In West Godavari district, there is a significant increase in minimum temperature (Fig. 9). In general, significant increase in maximum temperature was observed in most of the coastal areas which has direct effect on crop productivity.

Climate change impact on rice production in North coastal AP:

In recent years there has been severe reduction in yields of rice in some areas and stagnation of yields in some areas in North coastal Zone (NCZ) of Andhra Pradesh. An investigation was carried at Advanced Agroclimate Research Centre, Regional Agricultural Research Station, Tirupati for finding climate change impact on rice production in NCZ under Representative Concentration Pathway (RCP) 4.5. Crop simulation models with GCM’s can estimate the impact of future climate conditions on rice. DSSAT model was used for the study. Near future (2030’s), Mid century (2050’s) and far future (2070’s) were taken as time periods. Results showed that, in Visakhapatnam district, Aug 1st fortnight (FN) sowing has shown increase in yields (3.8%) by 2070’s compared to base line yields. Aug 2nd FN sowing has shown 2.24% increase in yields. In Srikakulam and Vizayanagaram all the sowing windows have shown decreasing yields. In Srikakulam yield reduction was ranged from -4.8% (2030's) in Aug 1st FN to -34.75% (2030's) in Aug 2nd FN sowing. In Vizayanagaram district the reduction in yields was ranged from -11.4% (2030's) in Aug 1st FN to -23.4% (2070's) in Aug 2nd FN sowing (Fig. 11).

Effects of cyclone on agriculture

Field crops, horticultural crops, agro-forestry plants, livestock, and fisheries are all included in the agricultural industry. All three aspects of the agricultural industry are significantly impacted by cyclones in coastal locations due to direct damage from high-speed wind, torrential rain, and significant floods. The fields may become unusable for farming due to saline water and sand mass brought in by high tide. The indirect effects include infection and disease of farm animals, fish and crop plants. Agricultural marketing and trade are adversely affected due to lean season of animal, fish and crop production (Rautaray and Pandey, 2014).

Adaptation strategies

Agricultural practises in coastal areas that are particularly vulnerable to SLR will change significantly due to salt intrusion and increased soil salinity, as well as floods and waterlogging brought on by a rise in the intensity and frequency of extreme weather events. Win-win techniques for eco-system services and climate resilience are needed to meet the increasing food demand while also maintaining coastal eco-systems in a changing climate. Agroforestry and tree-based farming, which boost carbon stores in the soil and biomass, as well as low-impact restorative aquaculture approaches, are essential for maintaining the ecological interconnectedness of these vulnerable ecosystems (Ayyappan and Kumar, 2022). Various adaptation strategies/technologies (Fig. 2) can be adopted which enhances the capacity of the farmers.

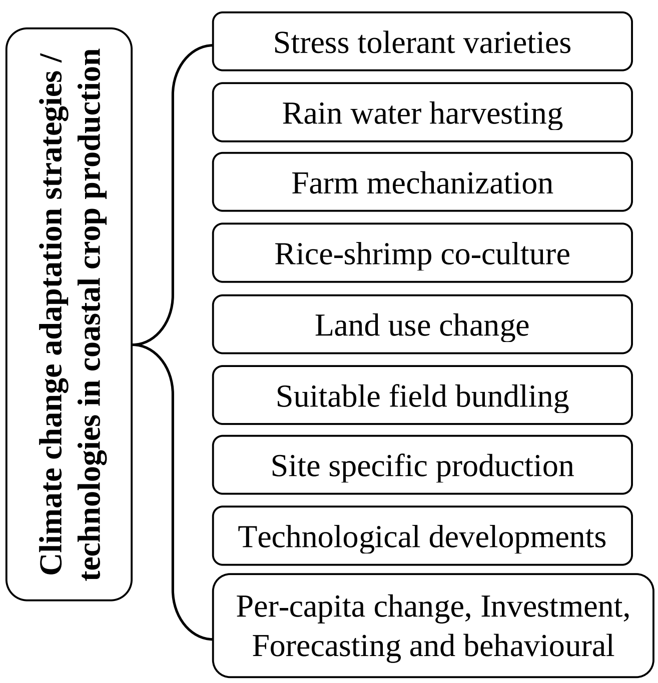


Fig. 2. Climate change adaptation strategies / technologies in coastal crop production)

The following adaptation strategies can be followed to overcome the cyclone effects,

1. Preparation of crop calendar based on monsoon period and peak period of cyclone.
2. Selection of recommended rice varieties for submergence tolerance, semi deep and deep water tolerance.
3. Early sowing / transplanting, use of high density and vigorous seedlings so as to escape/tolerate cyclonic storms.
4. Direct seeding with short duration rice varieties in damaged fields during cyclones.
5. Following suitable crop management technologies in flood affected fields like applying common salt 10% on ear heads @ 1000 L ha^{-1} at 20-25 days after flowering to enhance maturity by 1 week.
6. Following early warnings and facilitating for quick harvests using mechanisation.
7. Using salinity tolerate varieties in areas of intrusion of sea water in agricultural fields.
8. Soil amelioration by using organic manures like FYM, compost and green manures.
9. Provision of wind breaks around the agricultural fields.
10. Construction of flood protection domes and development of on-farm water control structures.
11. Awareness on cyclones, early warnings, post cyclone contingency measures, Technology based capacity building and training to agricultural farmers of coastal areas.

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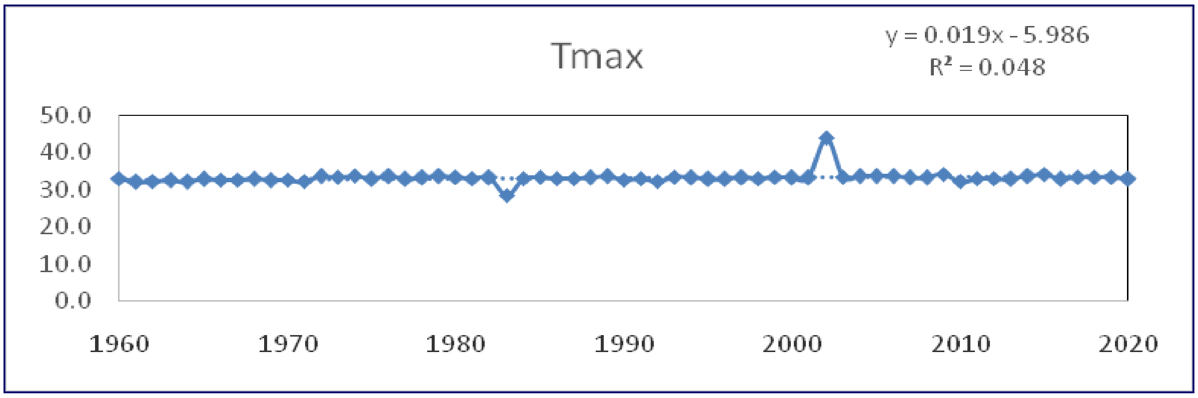

Fig. 3. Maximum temperature trend in Visakhapatnam district during *Kharif*

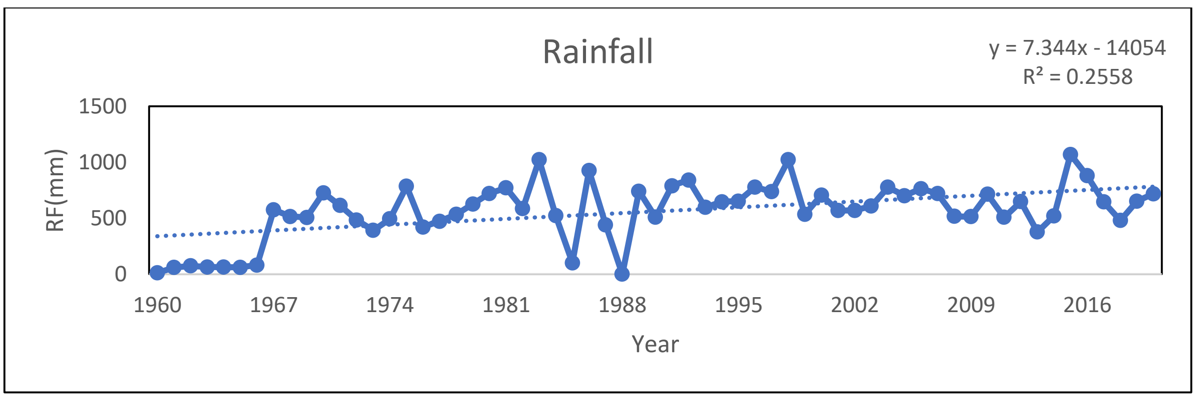

Fig. 4. Rainfall trend in Visakhapatnam district during *Kharif*

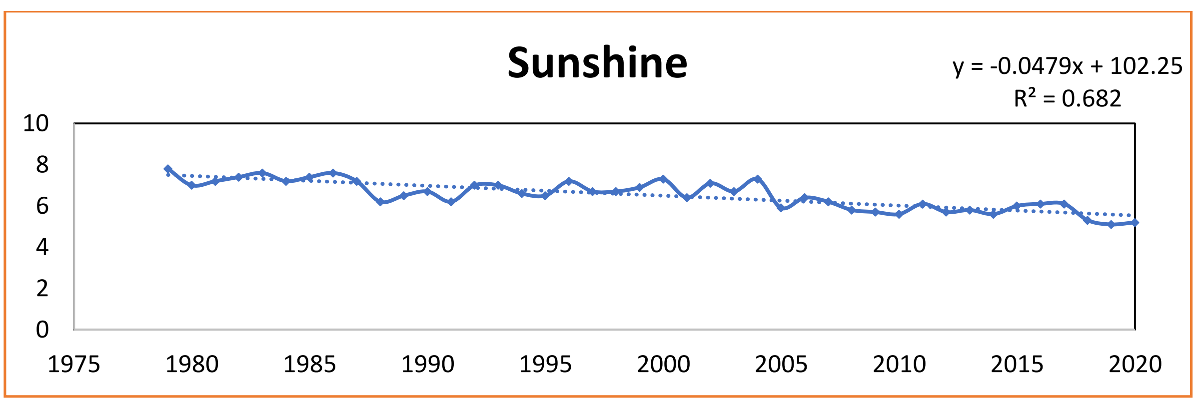

Fig. 5. Sunshine hours trend in Visakhapatnam district during *Kharif*

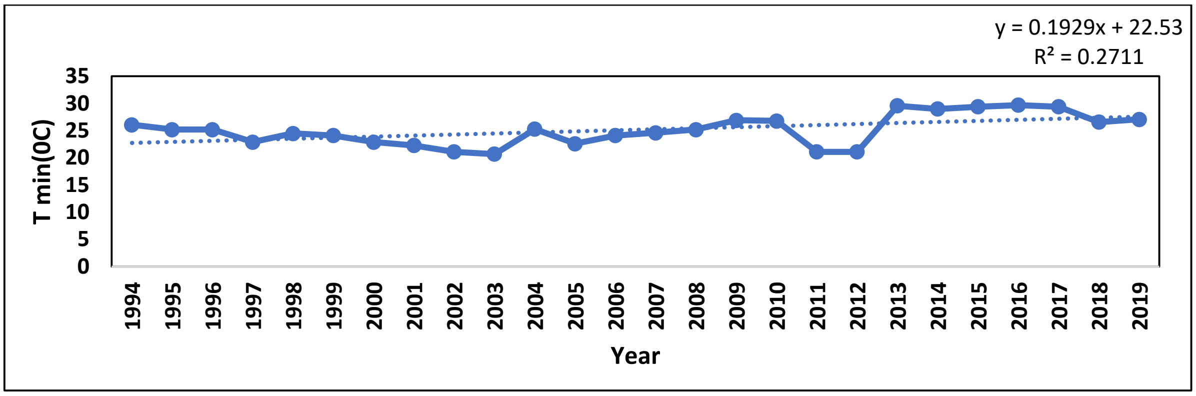

Fig. 6. Minimum temperature trend in Srikakulam district during *Kharif*

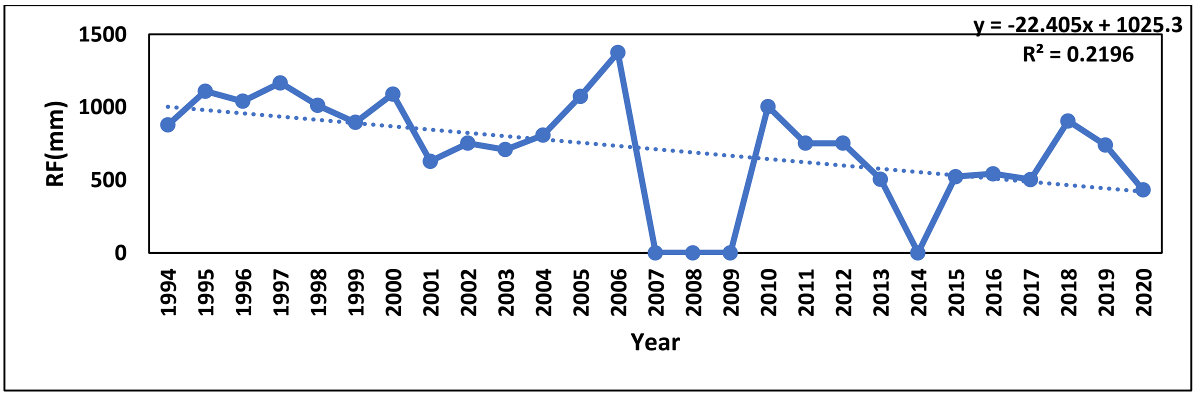

Fig. 7. Rainfall trend in Srikakulam district during *Kharif*

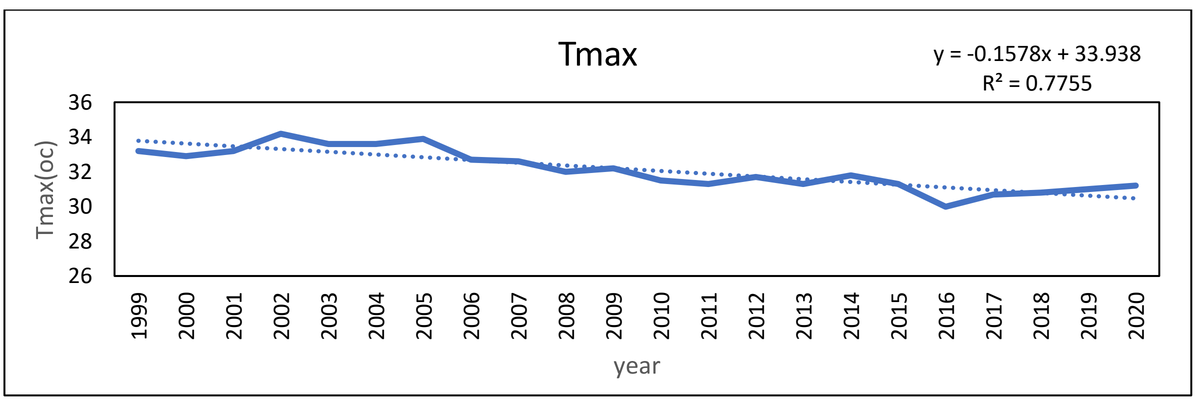

Fig. 8. Maximum temperature trend in Vizianagaram during *Kharif*

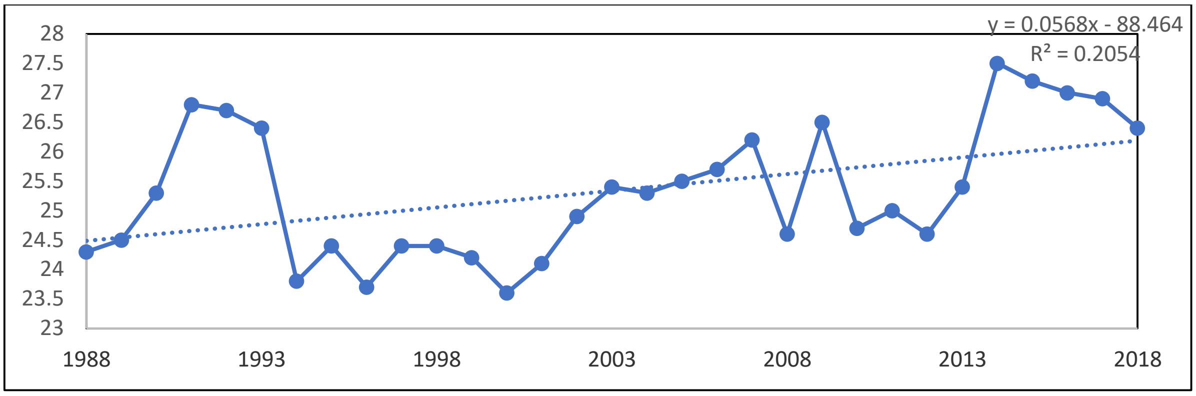

Fig. 9. Minimum temperature trend in West Godavari during *Kharif*

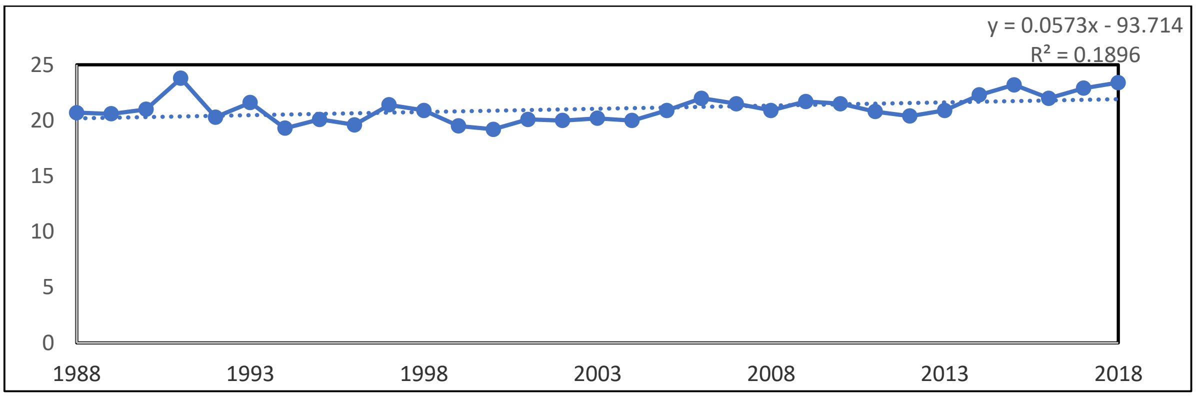

Fig. 10. Minimum temperature trend in West Godavari during *Rabi*

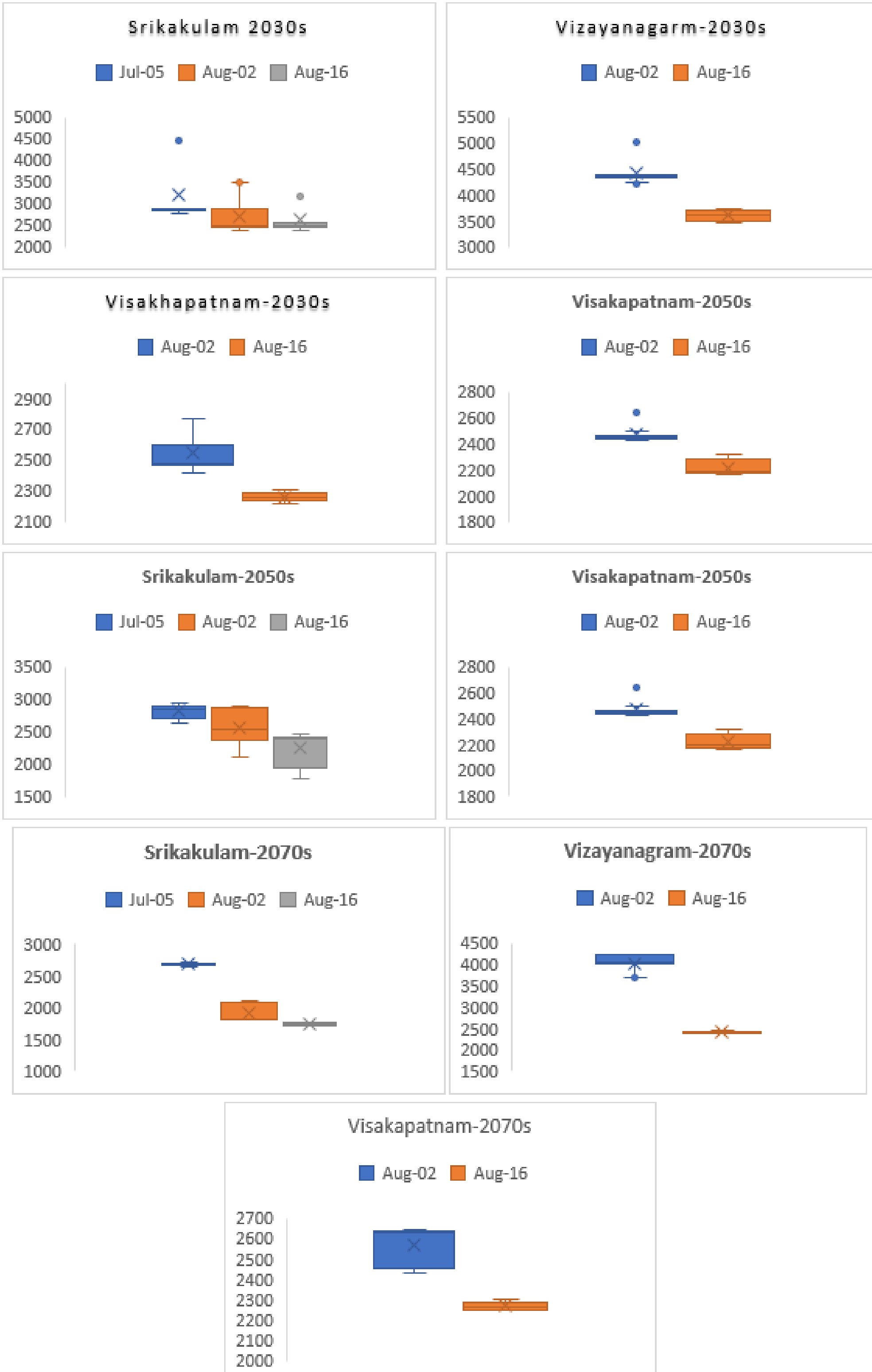

Fig. 11 Variation in simulated yields

Coastal Agriculture @ Nanotechnologies : A Future Perspective

T.N.V.K.V. Prasad, B.P. Girish, M. Swethasree, K.V. Naga Madhuri,
M. Madan Mohan and Ch. Bharghavarami Reddy

Nanotechnology Laboratory, Institute of Frontier Technology, RARS, ANGRAU, Tirupati – 517 502, A.P., India
Corresponding author: tnvkv.prasad@angrau.ac.in

Indian subcontinent is a peninsula with considerable costal area spanning approximately 7517 km, which spread across 9 states and 4 union territories. Gujarat is having largest share (23%) in India's coastal line, followed by Andhra Pradesh and Tamil Nadu. Indian coastal ecosystems are bestowed with profuse natural resources. In India, river deltas are rich in fertile alluvial soils, which provide excellent source of nutrients for cultivation of rice. In general, the soils of coastal areas are calcareous, poorly drained, sandy to fine loamy, slightly to moderately saline and alkaline. Heavy exploitation of groundwater coupled with changes in land configuration in many coastal areas has resulted in seawater intrusion and development of high soil salinity, which has become one of the significant constraints for improving farm production even though the agro-climatic condition is suitable for different crops and farming systems.

There are many crops grown in this region including plantations of bananas, coconut, arecanut, cashewnut and rubber mostly in the western coast. Despite of good potential for agriculture, the yield gap for various crops varies from 0.5 to 2.5 t ha^{-1} and the cropping intensity ranges from 150% to 200%. To overcome yield gaps, many issues must be addressed with regard to coastal agriculture like salinity, nutrient availability in soil, saline air produced by temporal ocean activities, flooding and erosion of coastal lands. Soil salinity in costal areas impose severe stress in plants, thereby causes many phenotypical and genotypical changes. The plants can tolerate to low levels of salinity through innate mechanisms adapted by plant, but increased salinity may cause irreversible damage. Alleviation of salt stress in the coastal soils may provide suitable conditions for cropping systems. Desalination of water can be achieved by using synthetic membranes but it has many limitations like decreased water

flux, biofouling, low membrane life, salt removal and reduced hydrophobicity. In recent times, emerging technologies like nanotechnology provided exemplary results with respect to desalinization of water and soils. Nanomaterials, which are capable enough to desalinate the costal soils along with nutrient supplement potentiality must be preferred for coastal agro systems.

Understanding and manipulating matter at atomic and molecular scale and developing materials, devices, or other structures possessing at least one dimension with less than 100 nm size is referred as Nanotechnology. The scope of nanotechnology in the field of Agriculture is very wide. The primary area of focus includes productivity and management of crops includeing pesticides, fertilizers, water, gene, inputs for remediation of natural resources and other input delivery formulations in plants and animals, precision agriculture, soil and water management, pest and disease diagnosis, food processing, and packaging.

A specific **SWOT** analysis of the application of nanotechnologies in the field of coastal agriculture has been described in the following text.

Strengths

The nanotechnology has the potential to address most of the major issues related to coastal agriculture. These include: -

- Using nanoscale materials, smart delivery systems could be developed for controlled release of nutrients, herbicides, pesticides *etc.*, to minimize the losses due to run-off and leaching of agricultural inputs and to enhance the input efficiency.
- Nanoparticle aided effective gene delivery in plants to combat with the climate changes
- Enhancing the potential yield of crops with the application of nano-stimulants by altering the physiology of the crop plants.
- Removal of contaminants from soil and water of coastal region using nanoscale composite materials.

Weaknesses

Although, nanotechnology is a buzzing word in the recent times, Indian agriculture is not familiar with this due to several reasons including:

- The concept of nanotechnology is relatively new, and the available trained manpower is limited.
- Lack of infrastructure and required policy framework for nanotechnology research in agriculture in India is a major weakness.
- Lack of knowledge on the nano based product / processes for customized utilization.

Opportunities

Nanotechnology possesses tremendous applications in coastal agriculture and the opportunities of this technology are listed below.

- Nanotechnology based growth in coastal agriculture sector may lead to generate income and employment opportunities
- Nanotechnology based food preservation practices including packaging may increase the number of coastal agriculture based value added products and which in turn being reflected in significant economic growth of the coastal farmers
- Adaptation of nanotechnologies in coastal agriculture certainly would help to ensure food and nutritional security in the country as food is of primary concern of any country including India.

Threats

However, the negative impact of nanotechnologies is as follows

- Presence of nanoparticles beyond certain level in the particle form in food chain may create health risks to human beings and other living organisms
- Nanotechnologies expected to release nanoparticles in to the environment and which may cause a serious damage to the exposed environment,
- Nanotechnology based food products may be deceived by the public in the similar lines as in the case of GM foods

Conclusion

At present, agriculture in India is at the cross roads and plateauing of yield, degradation of natural resources, invasion of new types of pests and pathogens, ensuring food and nutritional security including hidden hunger, mitigating the impact of climate change and producing more from declining land and water were the issues to be addressed and needs immediate attention by the scientific community. In this context, nanotechnologies can provide sustenance to our food production in multiple ways and there is a dire need to focus on these technologies and large group of trained man power is required for the development and the effective implementation of nanotechnologies in adequate and coastal agriculture in particular.

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Soil Health Management Strategies for Sustainable Coastal Agriculture Productivity

K.V. Naga Madhuri, P.V.R.M. Reddy, M. Raveendra Reddy, M Madhan Mohan,
Ch. Bhargava Rami Reddy, T.N.V.K.V. Prasad, M.V.S. Naidu,
G. Sashikala and P.R.K. Prasad

Regional Agricultural Research Station, Tirupati
Acharya N.G. Ranga Agricultural University, Guntur

The coastal soils represent the transition from terrestrial to marine affects and *vice-versa*. It contains not only shoreline ecosystems, additionally the upland watersheds draining into coastal waters, and the close to shore sub-littoral ecosystems influenced via land-based activities. Functionally, it is a vast interface between land and sea that is strongly influenced with the aid of each. India has an 8129 km long coastline and its peninsular area is bounded with the aid of the Arabian sea on the west, the Bay of Bengal on the east and Indian ocean to its south. It has two distinct fundamental island ecosystems, the Andaman and Nicobar group of Islands within the Bay of Bengal and the Lakshadweep Islands in the Arabian Sea. Coastal ecosystem in India occupies a place of approximately 10.78 million hectares (1,07,833 km2). In India, coastal area covers a long strip along the east coast (West Bengal, Orissa, Andhra Pradesh, Pondicherry and Tamil Nadu) and west coast (Gujarat, Maharashtra, Karnataka and Kerala). It additionally occupies great region beneath Lakshadweep and Andaman and Nicobar organization of Islands.

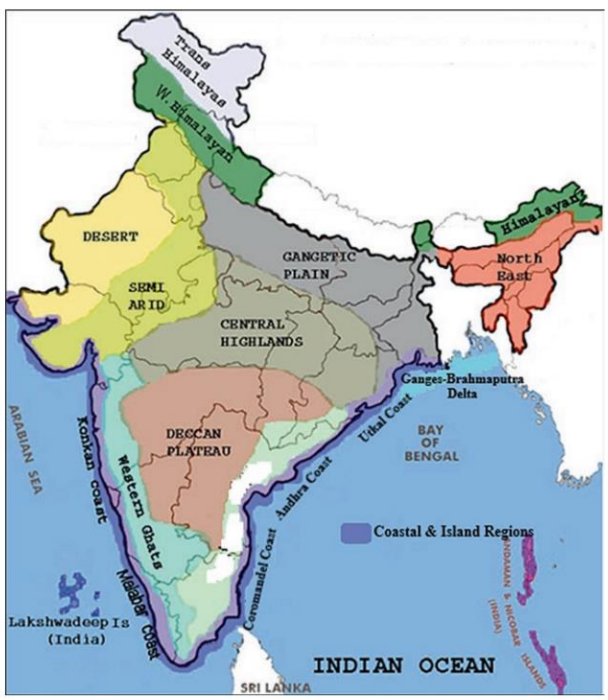

Fig. 1. Map of India displaying geographic regions as effecting its bio-diversity"
(Singh, 2020)

The sustainability of agriculture in the coastal ecosystem is seriously threatened by unfavorable agro-climatic conditions. Coastal soils are encountered with diverse abiotic stresses *viz.*, salinity, acidity, waterlogging and sandy texture. Most of the coastal regions have problem soils, such as saline, alkaline, acid sulphate, marshy and waterlogged soils, located in low lying regions, mainly along the deltas. Salinity is the main aspect chargeable for poor yield of crops developing a place of approximately 3.1 million hectares. The estimate at the extent of acid sulphate soils within the coastal areas well-known shows that about 0.26 million hectares in Kerala and the Andaman and Nicobar organization of islands are occupied through this kind of soil. In India, presence of acid sulphate soils has also been mentioned in the coastal regions of Sundarbans, West Bengal. Coastal soils exhibit a wide diversity due to difference in coastal soils and exhibit a great deal of diversity towing to differences in parent material, wide diversity of weather, physiography, differentially energetic agradational/degradational/geomorphic approaches, hydro-chemical traits of shallow underground water and differential inundation by tidal marine/lacustrine waters. Therefore, a suitable soil and water management strategies is therefore required to mitigate the ill effects of degraded coastal land for sustained productivity.

Table 1. Extent and distribution of coastal area in India

States/Union territories	**Area (km^2)**
West Bengal	14,152
Orissa	7,900
Andhra Pradesh	35,500
Tamil Nadu	7,424
Kerala	7,719
Karnataka	7,424
Maharashtra	10,000
Goa	220
Gujarat	17,465
Andaman & Nicobar	
Lakshadweep	26
Pondicherry and Karaikal	3
Total	**1,07,833**

Source: Velayutham *et al*. (1998)

Characteristic of coastal soil

Soils of coastal areas are generally deep to very deep having coarse sandy to fine loamy texture. The soils are calcareous, slightly to moderately saline and alkaline. In many coastal areas uncontrolled mining of ground water has resulted in intrusion of sea water and development of high salinity (Velayutham *et al.*, 1998).

Saline soils

Coastal soils are high in salts, because of the presence of saline ground water table at shallow depths and brackish water inundation within the low-lying areas. The ground water stimulated by using sea and brackish water estuaries reaches the soil floor through capillary rise at some stage in dry season, evaporates from the soil leaving salts at the back of, in the end making the soil are saline and unproductive for agricultural crops. The soil salinity accordingly suggests excessive temporal and spatial variant relying at the elevation, soil texture, weather (evapo-transpiration, precipitation, wind velocity, relative humidity and so on.), drainage and different related elements. The salt-encumbered sands blown through sea winds also are greatly accountable for formation of coastal salt-affected soils.

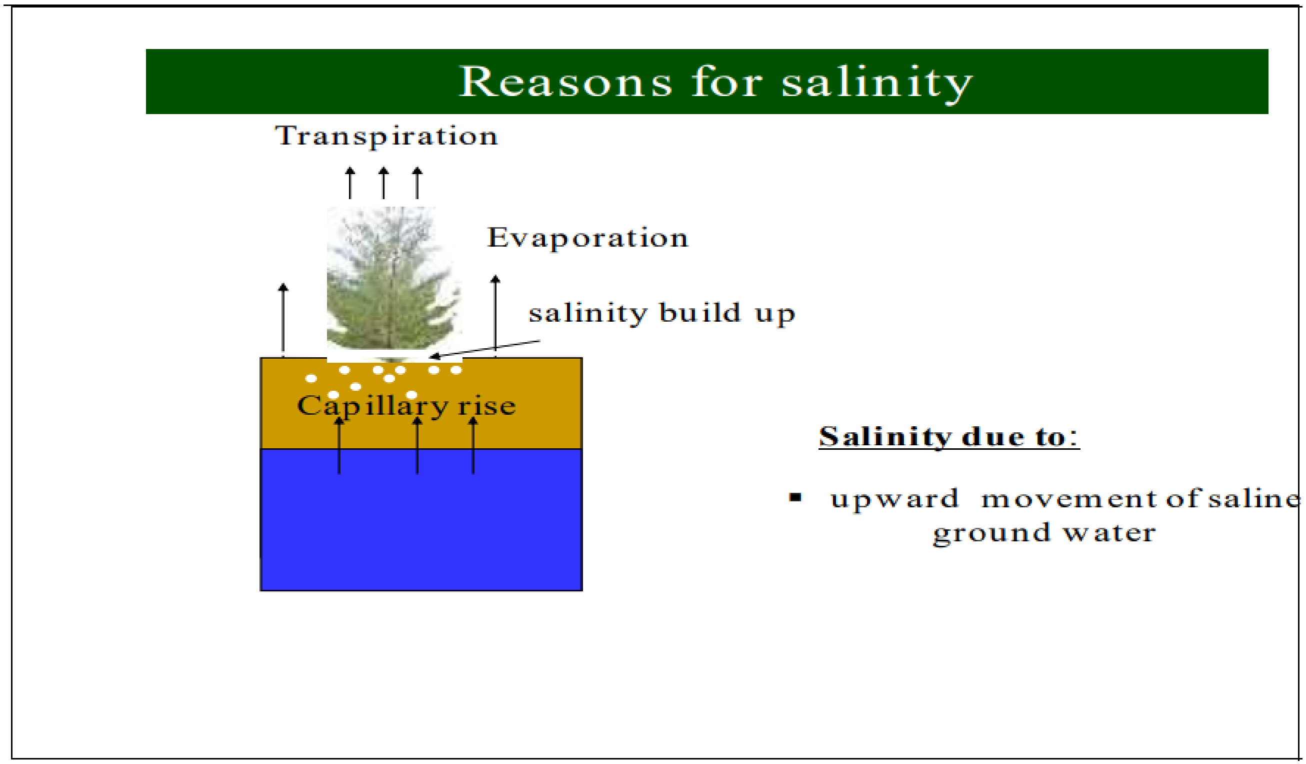

Fig. 2. Process of formation of saline soil

Acid sulphate soils

Many of the coastal soils are developed under coastal swamps and mangrove forests leading to the environment of high organic matter and abundant supply of sulphate salts from the sea.

$$2Fe_2O_3 + 8SO_4^{2-} + 16CH_2O + O_2 \longrightarrow 4FeS_2 + 16HCO_3^- + 8H_2O$$

$$12FeS_2 + 45O_2 + 30H_2O + 4K^+ \longrightarrow 4KFeS2_3(SO_4)_2.(OH)_6 + 16SO_4^{2-} + 36H^+$$

(Jarosite mineral)

Improvement of acid sulphate soils in coastal areas is the result of the drainage of soils that are rich in pyrites (FeS_2) and upon which oxidation produce sulphuric acid in presence of excess sulphate ions present in the soil. Pyrites accumulate in waterlogged soils that are rich in both soil organic matter (SOM) and sulphate ions.

High permeability of coastal soils

High permeability and poor nutrient retention capacity are associated with sand and loamy sand texture of coastal soils (Entisols, Aridisols and Inceptisols). Due to high permeability, most of the rainwater is lost in deeper soil layers and the availability of water in the upper soil profile is only for a short period. The high permeability and poor nutrient retention capacity of soils reduce the water and fertilizer use efficiency and cause waterlogging in areas having impervious layer at shallow depths. The low fertilizer use efficiency and high nutrient loss discourage farmers from using high levels of inputs, resulting in low yields crops in coastal agriculture.

Properties and constraints of coastal soils

Characteristics of soils present in coastal areas are broadly variable, relying on fertility, physiographic and climatic situations. In general, soils of the coastal region are less fertile and poor in organic matter content, ranging from less than 1%–1.5%. The low organic content indicates poor physical condition of the coastal soils. The total nitrogen contents are generally low, mostly around 0.1%. Generally coastal soils are saline with electric conductivity ranging ranging from 0.5 dS m^{-1} during monsoon to 50 dS m^{-1} during summer season. Among the soluble salts NaCl is the most dominant followed by Na_2SO_4. However, in acid sulphate soils of Kerala, Andaman and Nicobar Islands, Na_2SO_4 is the dominant salt. The cations present along with soluble salts follows the order: $Na^+ > Mg^{+2} > Ca^{+2} > K^+$. whereas the chloride is the fundamental anion with traces of bicarbonates only. The soils are general free from sodicity, except in few pockets of south and west coast, where the SAR exceeds 15 and attains the SAR value up to 40. the majority of the soils alongside the coasts are barely acidic to impartial or impartial to slightly saline and alkaline. A generalised characteristics of coastal soils presented here under in Table 2.

Table 2. Soil characteristics at different coastal places of the east coast

State/U.T.	pH	EC (dS m^{-1})	Dominant salt
West Bengal	3.5-7.0	4.0-35	NaCl, Na_2SO_4
Orissa	5.0-7.5	2.0-50	NaCl
Andhra Pradesh	6.0-8.8	0.5-17	NaCl, Na_2SO_4
Pondichery	6.6-8.5	1.0-50	-do-
Tamil Nadu	6.0-8.2	2.0-10	-do-
Andaman & Nicobar Islands	3.0-7.0	4.0-25	-do-

Source: Bandyopadhyay (1994)

Apart from the common problems of salinity or acidity, there are location specific problems, *viz.*, sea-water intrusion in un bunded low-lying areas, iron toxicity in Orissa, impeded drainage in coastal Andhra Pradesh and Tamil Nadu along the east coast as well as in parts of Kerala and Gujarat along the west coast, highly permeable sandy soils in parts of Gujarat, and highly leached low-fertility lateritic soils with severe erosion problem along with undulating topography in some parts of Maharashtra, Goa, Karnataka and Kerala. The soils of Lakshadweep Islands are essentially coral sandy, calcareous and alkaline, whereas those of the Andaman and Nicobar group of islands are acidic, as well as low in organic matter and available phosphorus. Nitrogen recovery by the crops is very low due to heavy loss of the nutrient, particularly in saline and alkaline soils (by volatilization) and also in deep waterlogged areas (by leaching and run-off). The salient factors limiting crop growth in the coastal plains are: Excess accumulation of soluble salts and alkalinity in soil, predominance of acid sulphate soils, periodic inundation of soil surface by the tidal water, accumulation of salts and sediments by the natural calamities like tsunami, cyclone and shallow saline ground water, eutrophication and hypoxia. The major abiotic stresses common to coastal rice soils in Asia have been shown in Table 3.

Table 3. Major abiotic stresses common to coastal problem rice soils in Asia

Ecosystem	Major problem	Deficiencies	Toxicities	Other stresses
Rainfed and irrigated	Acid and acid sulphate soil	P, N	Acidity, sulphate, Aluminium, Fe, Salinity	Inhibition of nutrient uptake, flooding
	Peat (Histosols)	N, P, K, Zn, Mo, Cu and B	Acidity, Fe, H_2S, organic Substances	Waterlogging, low thermal conductivity
	Salinity	P, Zn, N	Salts (Ca, Mg, Na)	Submergence, stagnant flooding, drought

Source: Ismail *et al*. (2007)

Soil physical rating index (PI)

Computation of PI involved measurement of important physical properties such as soil depth, bulk density, infiltration rate, soil organic matter, available water storage capacity, non-capillary pore space, land slope and water table depth. For a given site, each of these parameters was assigned a rating value corresponding to its actual value by referring to rating chart (Gupta, 1986). Each of this parameter was given a score of 1 if the parameter value lies within the optimum range. If the value lies below or above the critical limit, a score less than 1 were given. Greater the deviation of parameter value from optimum range, lesser the score given to it. The product of rating values of all the eight parameters gave the physical rating index. PI was an indicator of overall soil physical health status. For range of PI >0.75, 0.50-0.75, 0.25-0.50 and <0.25, soil physical health status and accordingly its production potential could be labelled as very good, good, medium or poor, respectively.

Biological indicators

1. Microorganisms

Microorganisms are widely used as soil quality indicators. Soil contains a large variety of microbial taxa with a wide diversity of metabolic activities. Microorganisms play a key role in nutrient cycling and energy flow and provide information on the impact of intercropping, incorporation of organic matter, management practices, and tillage activities contributing to soil structure and stabilization. Microbial communities respond to environmental stress or ecosystem disturbance, affecting the availability of energetic compounds that support microbial population. Nitrogen is the most limiting crop nutrient; thus biological N fixation, particularly the development of productive associations of plant and N-fixing bacteria and possibly other free living N fixers, has the potential to provide an endless and low-cost source of N. Another important nutrient for many soils worldwide is phosphorus (P); many soils are inherently low in P and have high P adsorption capacity. Unlike N deficiency, which potentially can be corrected by biologically fixing atmospheric N_2, P deficiencies need to be corrected by adding P sources to soils and increasing P uptake efficiency. Besides biological N_2 fixation and P solubilization in the rhizosphere, microorganisms can enhance nutrient use efficiency by increasing root surface area e.g. mycorrhizal, fungi, promoting other beneficial symbioses of the host plant, and microbial interactions.

2. Metabolic substances

There are many metabolic substances that can be used as soil quality indicators; they include sterols, antibiotics, protein, enzymes, *etc.*

a. Ergosterol: Ergosterol, is the main endogenous sterol of fungi, actinomycetes, and some microalgae; its concentration is an important indicator of fungal growth on organic compounds and mineralization activity

b. Glomalin: Among these fungal components, glomalin, an insoluble and hydrophobic proteinaceous mix of substances, is of particular interest. Glomalin as glomalin-related soil protein (GRSP) has been proposed to improve the stability of soil by avoiding disaggregation by water . Many studies revealed that the plants, inoculated with different isolates of *Glomus mosseae* and *Glomus intraradices* in a microcosm experiment, found significantly higher aggregate stability (as mean weight diameter (MWD) of macro aggregates of 1–2 mm diameter), in mycorrhizal soils compared to non-mycorrhizal ones and the GRSP concentration and soil aggregate stability were positively correlated with mycorrhizal root volume and weakly correlated with total root volume.

c. Enzyme activities: Soil enzymes play biochemical functions in the overall process of organic matter decomposition in the system; they are important in catalyzing several reactions, necessary for the life processes of microorganisms in soils, the stabilization of soil structure, the decomposition of organic wastes, organic matter formation, and nutrient cycling, providing an early indication of the history of a soil and its changes in agricultural management. Thus, they have been studied as indicators of soil quality from the decade of the 80's. Many soil biologists reported enzymes as good indicators because: a) they are closely related to organic matter, physical characteristics, microbial activity and biomass in the soil, b) provide early information about changes in quality, and are more rapidly assessed.

Phosphatase: Phosphorus is an essential nutrient for plant growth and crop yields, however a large portion is immobilized because of intrinsic characteristics of soils such as pH that affects the availability of nutrients and the activity of enzymes, altering the equilibrium of the soil solid phase. Soil microorganisms play a key role on phosphate solubilization with the release of low molecular weight organic acids and production of extracellular enzymes as phosphatases. In soil, phosphomonoesterases have been the most studied enzymes probably because they have activity both under acidic and alkaline conditions, according to its optimal pH, and because they act on low molecular P-compounds including nucleotides, sugar phosphates and polyphosphates; thus they can be used as soil quality indicators.

Dehydrogenase: Dehydrogenase enzyme activity determination is attractive due to the fact they are an integral part of microorganisms and are involved in organic matter oxidation. it has been considered as a soil quality indicator, because it is involved in electron transport systems of oxygen metabolism and requires an intracellular environment (viable cells) to express its activity. Consistently, the activity of this enzyme is not present in extracellular form as hydrolases (β - Glucosidase, urease, phosphatase), which suggests, that it is not an enzyme that can be used to evaluate the processes of soil degradation, since its activity fluctuates as microbial activity does, in response to management practices and/or climatic effects.

Urease: These enzymes are involved on urea hydrolysis into CO_2 and NH_3 and consequently with soil pH increase and N losses by NH_3 volatilization. Urease has been widely used to evaluate changes on soil quality related to management, since its activity increases with organic fertilization and decreases with soil tillage. This enzyme, mostly the cases is an extracellular enzyme representing up to 63% of total activity in soil. It has been show that its activity depends on microbial community, physical, and chemical properties of soil, and its stability is affected by several factors: organo-mineral complexes and humic substances make them resistant to denaturing agents such as heat and proteolytic attack. Urease activity is used as a soil quality indicator because it is influenced by soil factors such as cropping history, organic matter content, soil depth, management practices, heavy metals and environmental factors like temperature and pH. The understanding of urease activity should provide better ways to manage urea fertilizer, especially in warm high rainfall areas, flooded soils and irrigated conditions.

Management practices to improve productivity of Coastal Soils

Leaching the soil

As a hydro-technical method of reclamation, leaching is the removal of soluble salts beyond the root zone, especially in shallow rooted crops. The amount of water used for reclamation of saline soils depends on degree of soil salinity, quality of irrigation water, the soil depth to be reclaimed and the water application techniques. The process of leaching was successful in the depth of 0-10 cm by means of maximum leaching of salts by Mahendran, (2007). The other management technologies are, 1. Selection of tolerant varieties, 2. Use of organic matter, 3. Use of mulch, 4. Foliar application of fertilizers, 5. Fertilizer management, 6. Integrated nutrient management 7. Phytoremediation, 8. Green manures & green leaf manure, 9. Strip cropping (Manjunath, 2016).

Radial skimming well (Improved doruvu technology): To overcome these constraints, the skimming well technology has been evolved by the All India Coordinated Research Project on Management of Salt affected Soils and Use of Saline water in Agriculture, Bapatla Centre of Acharya N.G. Ranga Agricultural University, popularly known as ‘Improved Doruvu Technology’ to skim the shallow depth fresh water in coastal aquifer without disturbing the hydro-dynamic conditions (Raghu Babu, 2004). The system consists of a collector well with lateral collector lines installed at shallow depth. The collector lines are connected to the sump on either side and imbedded for the collection of lateral flow by digging a trench. Depending on the water table head above the collector pipes, the collectors are continuously charged with subsurface fresh waters throughout their length and water flow into the well under gravity. The recharge occurs due to precipitation, upstream canal seepage and also by recycling of irrigation water. As a result of this recharge, flow lines are sustained. The advantages of skimming well over the traditional doruvus is as follow: Over exploitation of ground water beyond the collector line depth is not possible, and it serves as control of saline ground water upconing problem (or) against sea water intrusion as commonly observed in lanka lands, the land wastage and water evaporation is avoided and can be used for productive purposes. This technology effectively facilitates the adoption of modern irrigation systems like drips and sprinklers and helps in improving upon the water use efficiency. If properly planned and installed, the systems can be used to create irrigation source as well as to control water table in the cultivable areas in the periods of submergence. With this system, sufficient water expected to be made available to rabi and plantation crops and effective usage of water through sprinkler and drip irrigation methods possible. The system also replaces the existing traditional ‘doruvus’

Land Shaping: Ridge and furrow cultivation -The land will be shaped into alternate ridges and furrows. The ridges will remain relatively free from drainage congestion and soil salinity. The rainwater stored in furrows will be used for initial irrigations during Rabi. The ridges will be used for vegetable and other high value crops round the year instead of mono cropping with rice in *Kharif*.

Avoidance of summer time fallow: Most of the coastal regions be affected by excess water in monsoon season with attendant of extended deep water submergence having detrimental effect on crop growth. Whereas in winter and summer season months, the capillary rise of the saline floor water impel the farmers to take best one rice crop in a year in the course of the monsoon season. Introduction of second rice crop all through the fallow periods, if good first-rate water for irrigation is available, can lessen the salinity level and increase the cropping intensity. The high salinity is due to the high evaporation price from soil during winter and summer season months, if ground water is at shallow intensity and rich in salt content material. In coastal regions, the supply of excellent good quality irrigation water is one of the principal issues. But, if sufficient irrigation water of precise quality is not available, crops like chilli, barley, linseed, sugarbeet can be grown whose crop cover will reduce evaporation and hence there might be reduction in soil salinity.

***Application of soil amendments*:** Application of lime and alkaline flyash in proper combination to the coastal acid sulphate soils is effective for amelioration to some extent. Rice husk biochar could be used as a substitute for liming materials to improve the quality of acid sulphate soils. Increase in the pH of acid sulphate soil due to application of rice husk biochar is well documented. Amending coastal sandy soils with polyacrylamide @ 100-120 mg kg^{-1} is useful for increasing the aggregation of soil, which in turn increases the water holding capacity of coastal sandy soil. This plays important role in highly permeable coastal sandy soils during dry summer months (Ray *et al.* 2014).

***Growing of suitable vegetation*:** In coastal areas, rice is the most foremost crop which is salt tolerant and may be grown underneath submerged condition. Rice cultivation promotes the leaching of salts from coastal saline soils. Adoption of rice crop in acid sulphate soils of coastal regions will increase the pH of soil and thus reduces the iron and aluminium toxicity. Choice of appropriate rice variety depending upon the salinity level and depth of water regime is pretty appreciable.

***Integrated nutrient management*:** Maximum of the coastal soils are deficient in nitrogen due to heavy loss via volatilization, leaching and run-off. Phosphorus deficiency is also a not unusual phenomenon in coastal acid sulphate or acid saline soils. Use of nitrogenous fertilizers could be very a lot vital to acquire higher yield of crop in coastal saline soils. Utility of rock phosphate as phosphorus source is especially useful for coastal acid saline soils. Long time fertilizer test showed tremendous reaction of rice crop because of application of nitrogenous fertilizers on coastal saline soils of West Bengal below rice-fallow cropping system. Integrated use of chemical fertilizers and farmyard manure (FYM) @15 t ha^{-1} is also a encouraged exercise for higher use of fertilizer nutrients in coastal soils.

The saline soils do not support plant growth primarily because of excessive salts in the soil solution which, due to high osmotic pressure, prevent absorption of moisture and nutrients in adequate amounts. Higher salinity condition exerts adverse effect on physical properties reduces drainage, aeration and microbial activity. The integrated use of inorganic fertilizers with organic amendments and biofertilizer has a great scope in coastal saline soils. Use of green or farmyard manure improved the N fertility status of soil with gradual increases in yield of crops. Higher dose of organic matter are required for the salt affected soils due to lower microbial activity in the soil. Beside this application of organics improved physical condition of soil and facilitate leaching of soluble salts. It also conserves moisture in the soil and dilutes the salt concentration for higher yield. Nutrient supply through green manure/ organic manures single or in combination with inorganic fertilizer is extremely important for the sustainability of crop yields on salt affected soils

***Paddy-cum-fish subculture*:** For powerful usage of land sources and betterment of livelihood of the local community in coastal areas, paddy-cum-fish lifestyle may be adopted in lowland areas of coastal regions without plenty affecting the productiveness of the soils. This may facilitate additional earnings era to the farmers struggling for survival inside the coastal areas and also uplift their socio-economic situation.

Conclusion

Moist and fertile soil conditions of coastal areas often provide a favourable environment for agriculture, which provides food and support to agro based industries and other sectors. However, temporal ocean/sea activities and competition for natural resources (land and water) and interactions (both negative and positive) with other sectors are on the rise, producing future challenges for coastal agriculture. Therefore, to meet these challenges an effective management of soil health for coastal areas needs to be attention by integrating sustainable agriculture, concentrating on reducing and/or ensuring control of negative effects on agriculture and other sectors and conserving natural resources. This would require carefull assessment of soil chemical, physical and biological health to minimize negative effects and maximize the contribution of various cropping systems present in coastal areas for sustainable development.

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Sustainable Land Development through Integrated Watershed Management Approach

P. Venkataram Muni Reddy[1], Kona Sasidhar[1], R.V. Sagar Kumar Reddy[1] and B. Janardhan Reddy[1]

[1] Panchayat Raj and Rural Development Department, Tadepalli, Guntur-522 501, Andhra Pradesh, India.
Corresponding author: venkat.agri@gmail.com

A watershed is an area that supplies water by surface or subsurface flow to a given drainage system or body of water such as a stream, river, wetland, lake or ocean [12]. The watershed management concept has been introduced to respond to the complex challenges of natural resource management and to ensure the efficient use of both natural and social capital of the district in addition to the state. Conventional ground-based sampling has proved costly and time-consuming. The newly improved satellite's repeated coverage provides an excellent opportunity to monitor land resources and evaluate land cover changes by comparing images acquired for the same area at different times. Changes like increased area under cultivation, conversion of annual cropland to horticulture, change in surface water bodies, afforestation or soil reclamation can be monitored through the use of satellite remote sensing.

In this context, to reduce the cost and time, satellite remote sensing has been used as an evaluation tool in many of the studies [1-3]. “Unfortunately, monitoring and evaluation have not got their share of attention and therefore has become very difficult to quantify and assess the changes made by the development programs which have taken place in natural resources and the livelihoods of people” [4-9]. “There is not often enough room for midterm adjustments in the ongoing programs due to the lack of a proper monitoring system. Therefore, the need arises to identify a quick and cost-effective technique for monitoring the impact of such development programs on a ‘before project – after project’ temporal scale as well as during the project implementation stage” [4-11]. Remote Sensing (RS) and Geographical Information Systems (GIS) have proven to be effective tools to monitor and manage natural resources to assess the impact of watersheds during pre- and post-development. Change detection in watersheds was observed by spatial and temporal databases and analysis techniques. The efficiency of the techniques depends on several factors such as classification schemes, the spatial and spectral resolution of the RS data, ground reference data and effective implementation of the result [13,14]. Therefore, the present study attempted to assess the spatial and temporal changes in the watershed. The objective of this study is to evaluate the changes in the cropped area, land use/land cover, vegetation vigor, rainfall, and soil moisture changes during the study period.

METHODOLOGY

Andhra Pradesh is situated on the south-eastern coast of the country and lies between 12º 33' 19º 09' of North latitude and 76º 38' - 84º 42' of East Longitude with a geographical area of 1,62,970 sq km. It is located east of Karnataka, south of Telangana, southwest of Odisha, and north of Tamil Nadu. Andhra Pradesh ranks as the 8th largest State in the country. Situated in a tropical region, the state has the 2nd longest coastline in the country with a length of 974 km. The state comprises two regions i.e., Coastal and Rayalaseema and it has divided into 13 districts. In the present study, 62 watersheds have been implemented under Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) project (Batch-1) during 2009-10. They are distributed over 6 districts viz. Srikakulam, Prakasam, Kurnool, YSR Kadapa, Chittoor and Anantapuramu districts. The spatial distributions of watersheds are shown in Figure 1.

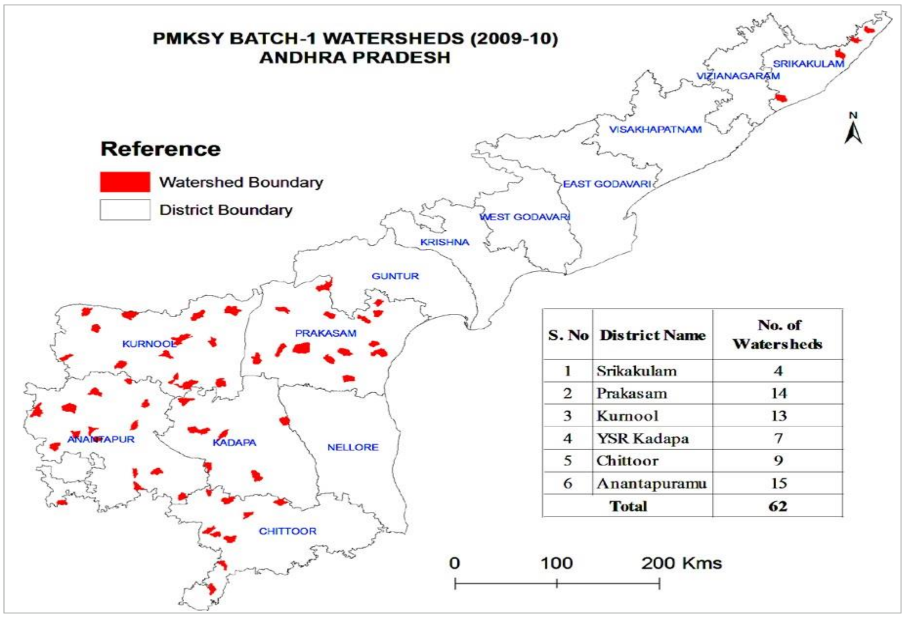

Fig. 1. Location map of watersheds

Remote Sensing based methodology is adopted through temporal satellite data for monitoring the watersheds [15]. This research study was investigated using high-resolution data like Resourcesat-2, and LISS-IV of 2011 (pre-treatment) and 2016 (post-treatment) to assess the changes in land use/land cover and biomass that have changed within a period of five years (2011-16). The methodology adapt for the study is presented in Figure 2. The land features were grouped into different land use/land cover categories using supervised classification by maximum likelihood algorithm with a minimum mapping unit of 2.5 ha.

The land area was classified into different vegetation levels using the Normalized Difference Vegetation Index (NDVI) approach. The classified outputs of land use/land cover and vegetation cover from NDVI of the two time periods were compared to derive information on changes that occurred over time for each watershed.

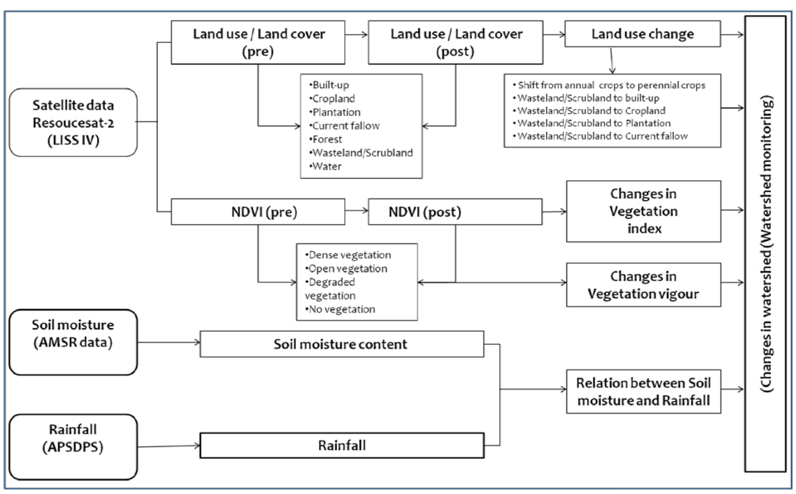

Fig. 2. Methodology

1. Land use / Land cover changes

Using the maximum likelihood algorithm, supervised classification was performed for both pre and post-treatment satellite data that have been clustered with a pixel of similar spectral characteristics into homogenous classes. This algorithm assumes Gaussian distribution and each pixel is considered a separate entity independent of neighbours. The classified output images have various land use/land cover categories about before and after treatment periods [16]. The output image has been used to compare and evaluate the changes which have taken place during the period.

2. Data used

The temporal satellite data is used for monitoring the watersheds. The study is executed using the following data sets: LISS IV satellite data (Pre & Post-treatment); Fusion (LISS IV + Cartosat-2) data; SOI topo sheets for reference; PMKSY monitoring reports from the department; Soil Moisture data from AMSRE-2 data; Rainfall data

3. Indicators considered for Evaluations of Watershed

To analyze the changes taking place during the project period, the following indicators are adopted: Vegetation cover; Water body area; Additional area brought under cropped area; Reclamation of wastelands

4. Major Developmental activities of the Watersheds

The developments will be the construction of structures like Loose Boulder Structure, Rock fill dams and check dams for soil water conservation; Farm ponds and percolation tanks; Plantations in individual farmer's land; Other works like drainage line treatment, Nala bank stabilization, filter strips etc., have also been developed.

RESULTS AND DISCUSSION

1. Changes in Land use / Land cover during 2011 and 2016

The satellite images of both periods (pre and post) were classified into different land use/land cover categories. The land use changes are shown in Figure 3. Table 1 shows the statistics of the area under different land use/land cover categories for both periods. An increase in cropland and plantations are observed, which is due to promoting agriculture and horticulture crops as well as scrub lands. Under land use, cropland occupied an area of around 115424 ha in 2011 and 162544 ha in 2016, indicating an increase of 47120 ha which is about 40.82% from its initial 115424 ha, which is due to a decrease of current fallow. The current fallow, which was 167533 ha (34.97%) during 2011 moderately decreased to 120017 ha (25.05%) in 2016 due to the implementation of drought-proofing works. The same portion of the current fallow was converted to cropland in 2016 [17-20].

Table 1. Land use / Land cover distribution and its changes (Units in Hectares)

S. No.	Land use/ cover class	Pre-Treatment		Post-Treatment		Change ±	
		Area	%	Area	%	Area	% Increase/ decrease
1	Built-up	8711	1.82	8995	1.88	284	3.26
2	Cropland	115424	24.09	162544	33.93	47120	40.82
3	Plantation	14848	3.1	19626	4.1	4778	32.18
4	Current Fallow	167533	34.97	120017	25.05	-47516	-28.36
5	Forest	52935	11.05	52763	11.01	-171	-0.32
6	Wasteland / Scrubland	99705	20.81	93187	19.45	-6518	-6.54
7	Water bodies	18331	3.83	20033	4.18	1702	9.28
8	Quarry area	1579	0.33	1900	0.4	321	20.35
	Total Area	**479066**	**100**	**479066**	**100**		

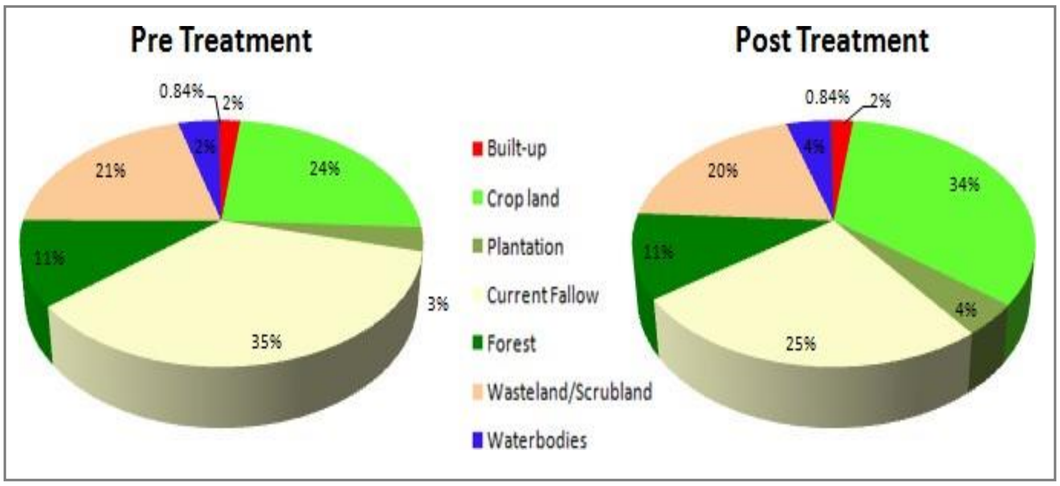

Fig. 3. Land use / Land cover distribution

1. Changes in Water body Area

Changes in water body area are a good indicator of any watershed intervention activities. The water body area is extracted using LISS-IV satellite data for 2011 and 2016 which showsa gradual temporal change in the water body area is being noticed. The increase in the water body area from 18331 ha to 20033 ha [17,18]. This is due to the construction of farm ponds, percolation tanks and check dams.

2. Shift from Annual crops to Perennial crops

The plantation covers occupied 14848 ha (3.10%) in 2011 and it has increased to 19626 ha (4.10%). It is found that 4778 ha of croplands are converted into perennial crops during the project period which is attributed to plantations in 2016 [17-20]. This may be helpful to protect from soil erosion, improve soil structure, increase ecosystem nutrient retention, carbon sequestration, and water infiltration, and it can contribute to climate change adaptation and mitigation.

3. The additional area brought under the cropped area

Due to the implementation of the watershed developmental activities, the cropped area increased from 2011 to 2016 which is about 47120 ha of the additional area brought under cultivation [17,18].

4. Reclamation of wastelands

Under the watershed development activities, the reclamation of wastelands is one of the major activities and it includes contour ploughing, strip farming, terracing, leaching and changing agriculture practices. Due to these activities, 6518 ha area is brought into cultivable land. In this, 2760 ha are converted into cropland and the remaining area is converted into fallow (3490 ha) and plantations (268 ha) [17,18].

CONCLUSION

Change detection studies have been carried out for the evaluation of 62 watersheds in the state and it is observed that due to soil and moisture conservation activities like the construction of farm ponds, percolation tanks, check dams, gabions, rockfill dams, loose boulder structures, etc., an additional area of 47120 ha has been brought under cultivation. There is an increase of 4778ha under plantation due to the conversion of fallow land.

An additional area of 1702 ha (9.28%) increased under water bodies and 6518 ha of wasteland was converted to cultivable land due to the construction of soil and moisture conservation structures.

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Major Challenges and Roadmap for the Livestock Sector: Special Reference to Coastal Ecosystem

G.V. Bhaskar Reddy, P. Amaravathi and Y. Ravindra Reddy

Department of Livestock Products Technology, College of Veterinary Science,
Sri Venkateswara Veterinary University, Tirupathi-517502, Andhra Pradesh, India

Animal Husbandry and Dairying plays an important role in development of India's economy. Animal Husbandry, Dairying and Fisheries sectors play an important role in the National economy and in the socio-economic development of the country. These sectors also play a significant role in supplementing family incomes and generating gainful employment in the rural sector, particularly, among the landless labors, small and marginal farmers and women, besides providing cheap nutritional food to millions of people. About 20.5 million people depend upon livestock for their livelihood. Livestock contributed 16% to the income of small farm households against an average of 14% for all rural households. Livestock provides livelihood to two-third of rural community. It also provides employment to about 8.8% of the population in India. India has vast livestock resources. Livestock sector contributes 4.11% GDP and 25.6% of total Agriculture GDP.

Improving the productivity of farm animals is one of the major challenges in the current scenario. The average annual milk yield of Indian cattle is 1172 Kg which is only about 50 per cent of the global average. The frequent outbreaks of diseases like Foot and Mouth Disease, Black Quarter, Influenza, *etc*. continue to affect Livestock health and lowers productivity. India's huge population of ruminants contribute to emission of greenhouse gases thus reducing greenhouse gases through mitigation and adaptation strategies will be a major challenge. Crossbreeding of Indigenous species with exotic stocks to enhance the genetic potential of different species was successful only to a limited extent. Limited Artificial Insemination services owing to a deficiency in quality germplasm, infrastructure and technical manpower coupled with poor conception rate following artificial insemination have been the major impediments. After more than three decades of crossbreeding, the crossbred population is only 16.6 per cent in cattle, 21.5 per cent in pigs and 5.2 per cent in sheep. Though globalization will create avenues for increased participation in International trade, stringent food safety, and quality norms would be required. The livestock sector received only about 12 per cent of the total public expenditure on Agriculture and allied sectors, which is disproportionately lesser than its contribution to agricultural GDP. The livestock sector has been neglected by financial institutions. The share of livestock in the total Agricultural credit has hardly ever exceeded 4% in the total (short-term, medium-term and long-term) GDP. The institutional mechanisms to protect animals against risk are not strong enough. Currently, only 6 per cent of the animal heads (excluding poultry) are provided insurance cover. Livestock extension has remained grossly neglected in the past.

Only about 5 per cent of the farm households in India access information on livestock technology. These indicate a sub-optimal outreach of the financial and information delivery systems. Livestock derives a major part of its energy requirement from Agricultural by-products and residues. Hardly 5 per cent of the cropped area is utilized to grow fodder. India is deficit in dry fodder by 11 per cent, green fodder by 35 per cent and concentrates feed by 28 per cent. The common grazing lands were deteriorating quantitatively and qualitatively. Likewise, slaughtering facilities are inadequate. About half of the total meat production comes from un-registered, make-shift slaughterhouses. Marketing and transaction costs of livestock products are high taking 15-20 per cent of the sale price.

Other major challenges faced by the sector are inadequate availability of credit, poor access to organized markets, limited availability of quality breeding bulls, water sources depletion, deficiency of vaccines and vaccination set-up, diversion of feed and fodder ingredients for Industrial use.

Major Challenges of Livestock Sector with a Special Reference to the Coastal Ecosystems

Low Potentiality of Livestock

Despite the fact that India possesses highest livestock population and number one in milk production in the world, the productivity, particularly of ruminants has been extremely low, turning this precious asset of the poor into a liability. Over 60 per cent of the rural households maintain large ruminants, mostly for milk and partly for bullock power. However, the average milk yield is significantly low. Since animal production of our cattle and buffalo is half of the world's average and it necessitates breed improvement. Breeds mainly can be improved with two methods one is crossbreeding and the other is up-grading. But there are many challenges in improving the breeds, like the availability of elite bull and lack of awareness among the farmers about the scientific breeding practices. Another challenge is the adoption rate of Artificial Insemination (AI) because it has only 24.5 per cent full adoption.

High Economic Losses

High economic losses due to animal diseases and these diseases in livestock pose major economic burden on the farmers. With improvement in the quality of livestock through cross-breeding program, the susceptibility of these livestock to various diseases including exotic diseases has been increased. The inadequate coverage of vaccination is continuously resulting into economic losses due to various animal diseases. The estimates of losses due to different diseases are not easy because all diseases at all places are difficult to report.

Inadequate Infrastructure and Human Resources

Inadequate infrastructure and human resources for support services to Indian livestock sector is suffering from poor infrastructure and human resources. As per the recommendation of the National Commission on Agriculture (NCA)-1976, One Veterinary Institution is to be provided for every 5,000 cattle units (one cattle unit =1 cow / 1 buffalo /10 sheep / 10 goats / 5 pigs / 100 poultry) to ensure proper Veterinary health care. Similarly, the Veterinary Council of India (VCI) has recommended that for every 5000 livestock population there is need of one Veterinarian for effective delivery of Veterinary services. Reports indicating that all states Animal Husbandry departments having severe shortage of Veterinarians and these highly inadequate human resources resulted in poor and inadequate Veterinary services to the farmers.

Shortage of Feed and Fodder

India with only 2.29 per cent of land area of the world is maintaining nearly 17 per cent of world human population and 10.70 per cent of livestock (more than 535.82 million heads) creating a huge pressure on land, water and other resources. The country is having only 5 per cent of its cultivable land under fodder production. Area under permanent pastures and grazing lands comprises a mere 3.30 per cent of the total area, and has been declining steadily. Among different resources, crop residues are major one and these feeding resources are meeting more than 50 per cent of the livestock sector demand in the country. At prevailing livestock productivity and production, livestock sector is facing severe feed and fodder shortage. In a report titled “Revisiting National Forage Demand and Availability Scenario”, released during August 2019 by the ICAR-Indian Grassland and Fodder Research Institute (IGFRI) has pointed out that there is a deficit of 23.40 per cent in the availability of dry fodder, 11.24 per cent in green fodder and 28.90 per cent for concentrates in India. There are already proven high yielding varieties of fodder and technologies such as silage making, hay making and urea- molasses treatment for crop residues. However, adoption of such technologies is very poor in many of the states in India. According to the Indian Ministry of New and Renewable Energy (MNRE) report, India generates on an average 500 million tons of crop residues per year.

Inadequate Public Institution Support

The livestock sector received only about 12 per cent of the total public expenditure on agriculture and allied sectors, which is disproportionately lesser than its contribution to Agricultural GDP. The sector has been neglected by financial institutions. The share of livestock in the total Agricultural credit has hardly ever exceeded four per cent in the total credit. (Short term, medium-term and long-term). The institutional mechanisms to protect animals against risk are not strong enough. Currently, only 6 per cent of the animal heads (excluding poultry) are provided insurance cover.

Inadequate Processing and Value Addition

Livestock product processing and value addition is being viewed as potential tool for sustainability of livestock production. As of 2018, the milk processing industry in India is expanded at a Compound Annual Growth Rate (CAGR) of 14.80 per cent. The meat industry is one of the most important parts of food processing industry. The processing rate of buffalo meat is around 21 per cent and 6 per cent for the poultry. The major reason for inadequate processing and value addition in meat product is lack of necessary infrastructure. As on year 2019, there are only 1377 slaughter houses, 68 Abattoirs with meat processing facilities approved by Agricultural and Processed Food Products Export Development Authority (APEDA), 32 APEDA registered meat processing plants, 11 APEDA registered stand-alone abattoirs, 9 carcass utilization centers, and 25000 small scale meat retail shops apart from few private companies. It is forecasted in Food and Agriculture Organization (FAO) 2011 report titled “Mapping Supply and Demand for Animal-Source Foods to 2030”, the demand for various livestock products will increase by 80-100 per cent in 2030 and out of total increase, nearly 60 per cent of demand will be due to change in consumption pattern and frequency of intake and remaining 40 per cent demand will increase due to increase in population. It clearly shows the importance of value addition and processing of livestock products.

Unorganized Marketing of Livestock and Livestock Products

Access to markets is critical to speed up the commercialization of livestock production. Lack of access to markets may act as a disincentive to farmers to adopt improved technologies and quality inputs. Currently, the livestock market does not undergo a uniform change. The changes are specific to species or products. But there are phenomenal changes from informal to formal market system in dairy and poultry. This can be attributed to the private industries participation. However nearly 60 per cent of milk is sold by the unorganized sector. On the other hand, sheep, goat and cattle meat remains in the informal sector without much investment from private players. In nutshell, the Indian livestock and livestock product market are mostly underdeveloped, irregular, uncertain, and lack transparency and often dominated by informal market intermediaries who exploit the producers.

Lack of Organized Small Ruminants Sector

The small ruminants *i.e.* sheep and goats are generally maintained by small, marginal farmers and landless, who cannot afford to own large ruminants. However, most of these small ruminants which are dependent on free grazing without any investment on supplementary feeding and health care, do not make significant contribution to the income. While the demand for meat is expected to grow high during the next two decades, the present system of unsustainable husbandry practices highlights the status of these species deprived of technological and managerial support services.

Inadequate Extension Services

The delivery of livestock services has three components *viz*. providing technical services to the animals; Supplying technical inputs and educating the livestock farmers. Providing services to animals involves vaccination, deworming, breeding and disease management services for which technical inputs such as vaccines, medicines, semen, AI guns, syringes and needles etc., have to be supplied. The livestock farmers have no option but to depend on Vets or para-Vets for all the above services and, to some extent, supply of technical inputs. Unfortunately, the third component, educating livestock farmers on various aspects of livestock management, (feeding, vaccination, disease management, breeding etc.) is grossly neglected. Many times, supply of inputs and providing services are considered as an extension service ignoring the fact that "education of farmers is the core of livestock extension service". The focus of any extension services needs to be on building the capabilities of the farmers to take care of their animal and crop apart from transfer of technology and strengthening of various infrastructure and support services. In most of the states, the designation of Veterinarians is Veterinary Officer (VO), Veterinary Assistant Surgeon (VAS) rather than Livestock Development Officer (LDO) which psychologically restricted their role on livestock development and building farmer's capacities. The Veterinarians are supposed to educate the farmers on scientific management practices, sustainability of livestock farming, ways to meet scarcity of animal feed and fodder, marketing of livestock, livestock products processing, environmental issues due to livestock, social entrepreneurship development etc. Thus, the development role of Veterinarians on livestock production aspect is not explored adequately in India. In spite of above challenges in the Indian livestock sector is performing well, however in view of fulfilling the increasing demand of livestock products, these needs to be addressed.

Way Forward

To minimize the input cost and productive utilization of the resources, a livestock-based integrated farming system is the need of the hour in respect to coastal ecosystems. An increasing trend of intensive livestock farming poses a threat of zoonotic diseases for the human population. Since livestock products are highly perishable, they require immediate processing, storage, and preservation, to move them from production areas to demand centers. Processing and market linkages are, therefore, prerequisites for value creation and addition. In the data-driven world, database management of animal information is necessary for monitoring and surveillance of various livestock development programs. To address the problem of the disposal of male animals, in cattle, sex-sorted semen technology should be promoted. In the case of buffaloes, the semen of the high genetic merit bulls should be made easily available to the farmers to improve productivity. There is a necessity to increase the insurance cover to shift the livestock owners' risk to insurance companies, as only 15.47 per cent of animals are under insurance cover. The area specific policy should be carried up as an example, in areas suitable for poultry production, policy focus should be towards poultry. The policy focus in rainfed areas should be on livestock rearing or livestock-based integrated farming system. The policies related to fisheries and aquaculture should be promoted especially in coastal ecosystems.

Roadmap for the Livestock Sector in India

Feeding Strategies

- Livestock derives a major part of their energy requirement from agricultural byproducts and residues and hardly 5% of the cropped area is utilized to grow fodder.
- India has a deficit in dry fodder by 11%, green fodder by 35% and concentrated feed by 28%.
- The common grazing lands have been deteriorating quantitatively and qualitatively.

Scientific Advancement

- Improving productivity in a huge population of low-producing animals is one of the major challenges.
- The average annual milk yield of Indian cattle is 1172 Kg which is only about 50% of the global average. Likewise, the meat yield of most species is 20-60% lower than the world's average.
- Crossbreeding of Indigenous species with exotic stocks to enhance the genetic potential of different species has been successful only to a limited extent owing to a deficiency in the quality germplasm, infrastructure and technical manpower.

Health Services

- Frequent outbreaks of diseases continue to affect livestock health and productivity.
- India has about 55,000 Veterinary institutions including polyclinics, hospitals, dispensaries and stockman centers.
- Veterinary and animal health services are largely in the public sector domain and remain poor.

Trade and Market Mechanism

- Globalization will create avenues for increased participation in International trade, stringent food safety and quality norms would be required.
- The global market for animal products is expanding fast and is an opportunity for India to improve its participation in the global market.
- Access to markets is critical to speed up the commercialization of livestock production. Except for poultry products and to some extent for milk, markets for livestock and livestock products are underdeveloped, irregular and lack transparency.
- Further, these are often dominated by informal market intermediaries who exploit the producers. Moreover, marketing and transaction costs of livestock products are high, taking 15-20% of the sale price.

Supporting Facilities

- Slaughtering facilities are too inadequate. About half of the total meat production comes from unregistered, make-shift slaughterhouses.
- Develop Forward linkages for wool, fibre, meat and milk such as cold storage, food processing industries and textile industries for the consumption of livestock produced.

Finance

- The sector received only about 12% of the total public expenditure on agriculture and allied sectors, which is disproportionately lesser than its contribution to agricultural GDP.
- The sector has been neglected by financial institutions.

Institutional Support

- The institutional mechanisms to protect animals against risk are not strong enough. Currently, only 6% of the animal heads (excluding poultry) are provided insurance cover.
- Only about 5% of the farm households in India access information on livestock technology. These indicate an apathetic outreach of the information delivery systems.

Conclusion

Stakeholders are ultimately admitting the structural shift in the Agriculture sector that has been happening for a decade. Livestock is the new growth dynamo of the Agriculture sector. The livestock sector has immense potential in the production, value addition, and export of dairy, fishery, poultry, and other products. Apart from performance, some challenges also exist that are posturing an impediment to sustainable production. We need to overcome these challenges to ensure nutritional security for the masses, achieving sustainable development goals, augmenting farmers' income, and grab global market opportunities.

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Agro-management Practices for Sustainable Coconut Production in Andhra Pradesh

N.B.V. Chalapathi Rao, A. Kireeti, V. Anoosha, B. Neeraja, V. Govardhan and B. Srinivasulu

Dr. YSRHU - HRS., Ambajipeta,
Dr B. R. Amedkar Konaseema district -533 214, Andhra Pradesh
Corresponding author: chalapathirao73@gmail.com

Coconut (*Cocos nucifera* L.), is the most beneficial and useful palm known to mankind and plays a conspicuous role in the economy of our country. In India the crop is cultivated in an extent of 2.150 million hectares with an annual production of 21.288 million nuts with 89.32% of the area and 91.94% of production concentrated in four southern states of Kerala, Tamil Nadu, Karnataka and Andhra Pradesh. In Andhra Pradesh coconut production is 1276 million nuts from an area of 1.14 lakh hectare with an average production of 12000 nuts per ha. Though coconut varieties and hybrids have the potential of yielding 20,000 nuts/ha. and yields upto 50-60 years, agro management practices like pre planting and post planting cultural operations, soil health and pest management plays a pivotal role in sustainable coconut production. Under the climatic change and resource constraint conditions, it is vital to develop and adopt scientific management practices to obtained desired genetic yield potential along with meeting the emerging pest challenges. The six decades of extensive research at Dr. YSRHU- HRS, Ambajipeta developed improved agro- management practices promoting sustainable yields for economic benefit of the farming community. Important agro-management practices for sustainable coconut production are detailed below.

Improving productivity through cultivation of improved varieties/hybrids of coconut in relation to abiotic stress

Coconut being a versatile crop, many value added products from inflorescence sap to root have good export demand. After the pandemic Covid-19, demand for the tender coconut water rose sharply in the global market. Likewise, virgin coconut oil, coconut shell charcoal and other various products are also gaining popularity in the international market. So based on the need of economically improved trait specific varieties and hybrids were developed at Dr.YSRHU- Horticultural Research Station, Ambajipeta, details are listed below.

S. No.	Name	Selection	Nuts/ palm	Nuts/ ha	Copra g/nut, t/ha	Oil (%)	Economic traits
1	Double Century	Phillipines Ordinary Tall	120-130 nuts	18000	190 g 3-3.2 t/ha	64	Dry copra and Oil
2	Kalpa Prathibha	Cochin China Tall	98	14700	228 g 3.3 t	67	Dry copra and Oil
3	Kera Bastar	Fiji Tall	110-117	19400	2.5-3.1 t	65	Good yield and copra

S. No.	Name	Selection	Nuts/ palm	Nuts/ ha	Copra g/nut, t/ha	Oil (%)	Economic traits
4	Gauthami Ganga	Gangabondam	80-90	12813	156.7 g 2.01 t	68	Tender nut water (467ml/nut)
5	Godavari Ganga	ECT x GBGD	140	24360	150 g 3.3 t	68	Dual purpose (Tender nut and mature nut)
6	Vasista Ganga	GBGD x PHOT	120-125	18750	158 g 2.8 t	69	Dual purpose (Tender nut and mature nut)
7	Vynteya Ganga	PHOT x GBGD	125-130	19000	168 g 2.9 t	68	Dual purpose (Tender nut and mature nut)
8	Abhaya Ganga	GBGD x LCT	136	20400	170 g 3.1 t	72	Coconut oil

Adverse climatic conditions like tropical cyclones affect coconut palms and the cyclones that were witnessed in the last decade in the state of Andhra Pradesh created catastrophe to plantation farmers by uprooting the palms, damaging the functional leaves and the spadices which were in varying stages of development in the crown region.

List of cyclones effected Andhra Pradesh in the last decade having impact on coconut cultivation

S. No.	Year	Cyclone name	Place of Landfall	Districts affected
1	2012	Nilam	Mahabalipuram , Tamil Nadu	Srikakulam, Vizianagaram, Visakhapatnam, East Godavari and West Godavari
2	2013	Mahasen	Chittagong and Feni, Bangladesh	Amalapuram div in East Godavari, Narasapuram div in West Godavari and Machilipatnam in Krishna
3	2013	Phailin	Crossed near Gopalpur , Odisha	Srikakulam, Visakhapatnam, Vizianagaram, East Godavari and West Godavari
4	2013	Helen	Machilipatnam , Andhra Pradesh	East Godavari and Krishna
5	2013	Lehar	Machilipatnam , Andhra Pradesh	East Godavari, West Godavari, Krishna and Guntur

S. No.	Year	Cyclone name	Place of Landfall	Districts affected
6	2014	Hud hud	Visakhapatnam , Andhra Pradesh	Visakhapatnam, Vizianagaram and Srikakulam
7	2016	Roanu	Chittagong , Bangladesh	Visakhapatnam Vizianagaram and Srikakulam
8	2018	Daye	Gopalpur , Odisha	Visakhapatnam, Vizianagaram, and Srikakulam
9	2018	Titli	Palasa, Andhra Pradesh	Srikakulam and Vizianagaram
10	2019	Fani	Puri , Odisha	Srikakulam, Vijayanagram and Visakhapatnam
11	2020	Nivar	Between Karaikal and Mamallapuram , Puducherry	Chittoor, Nellore, Kadapa and Guntur, East and West Godavari
12	2021	Gulab	Kalingapatnam , Odisha	Srikakulam, Vijayanagram and Visakhapatnam
13	2021	Jawad	Paradip, Odisha	Srikakulam, Vijayanagram and Visakhapatnam
14	2022	Asani	Machilipatnam and Narsapuram in Andhra Pradesh	Srikakulam, Vijayanagram and Visakhapatnam, East Godavari, West Godavari, Krishna and Guntur

Impact of cyclones on coconut palm may vary with the various factors where as, recovery pattern also varies based on the cultivars. The tolerance towards the effect of cyclones in talls and dwarfs is ambiguous and it may be vary with age of the palm, vigorous or sturdy growth character of palm, which will define the cyclone effect and recovery pattern of the coconut palms. The recovery of cyclone affected palms usually starts after 2 months after cyclone damage with production of new leaves. The spadices production will start after 4-5 months of damage and 2-3 years delay may be experienced in nut production in the palms affected by the cyclonic storms. However, past research revealed that dwarf cultivars with sturdy bole are tolerant to cyclones and this is strengthened by recent finding that compact dwarfs grown in Fiji having wide and thick solid stems are quite tolerant to cyclones. Development of hybrid dwarf coconuts will hold the key for developing climate resilience cyclone tolerant coconut. Likewise, drought tolerance is one character to be focused as coconut is grown under rain-fed conditions by and large, where long dry spells of more than 4- 5 months adversely affect the yield to the extent of 50%. Under this circumstances, selecting talls and hybrids (with talls as mother palms) had better drought tolerance than the dwarfs and the hybrids (with dwarfs as mother palms). Some of the tolerant coconut varieties and hybrids to drought conditions recommended are Chandra Kalpa, Kera Sankara and Chandra Laksha developed by ICAR- CPCRI, Kasargod, Kerala. The selection of coconut varieties or hybrids based on economic traits is a factor, helps to stand in the international market and fetch good price.

Quality planting material and way of planting for long term yields

The yield performance of the coconut crop will be known only after several years (yield stabilizes after 10-12 years) of planting as it is a perennial crop, improper selection of seedlings leads to considerable economic loss to the farmer for several decades. The characters like earliness in flowering, nut yield and copra production makes the seedling selection highly relevant for sustainable coconut farming. One year old seedlings usually show vigor for collar girth, number of leaves (more than six) and its splitting are recommended for planting . Recommended planting is June to July in the uplands and October to November in low lying and heavy rainfall regions spacing of 8 x 8 m (Talls) or 7.5 x 7.5 m (Hybrids).The number of seedlings to be planted per hectare is 150.

Coconut based high density multi cropping systems

In the studies at Dr. YSRHU-HRS, Ambajipeta, Andhra Pradesh conducted during 1999 to 2008, the crop combination of coconut + cocoa + cinnamon + pepper + pineapple + banana + elephant foot yam + colocasia + turmeric was found highly productive and remunerative. The high density multi species cropping system (HDMSCS) is growing a number of compatible crops in a unit area to meet the diverse needs of a farmer such as food, fuel, timber, fodder and cash. This system aims at maximizing production per unit of land area and is ideally suited for smaller holdings. The productivity of land increases in the high density multi species cropping system due to crop diversification and intensification. Growing of intercrops in a high density multi-species cropping system improves the available nutrient status of soil due to addition and recycling of organic matter. The research results on identification of suitable intercrops with profitable income in coconut revealed that banana, cinnamon, cocoa, black pepper, pineapple, elephant foot yam, colocasia and turmeric are suitable intercrops in coconut. Two models *viz.*, Model-I (Coconut + Pepper + Banana + Cocoa + Pineapple + Cinnamon) and Model-II (Coconut + Banana + Yam + Turmeric) were tested along with mono cropping of coconut (Model-III) which revealed that coconut yields were promoted with inter cropping in addition to doubling of income/unit area. Highest net returns were observed with Model- I followed by Model-II compared to mono cropping of coconut in Model-III. Cost benefit ratio also showed that model-I is more profitable with 3.22 compared to other models.

Good horticulture practices for sustainable yields

Integrated Nutrient Management

Integrated Nutrient Management (INM) is based on optimizing the use of organic, inorganic, and biological components in an integrated manner with an aim of maintaining soil fertility without affecting plant nutrient supply. Fertilization recommendations for matured coconut palms is N 460 g, P_20_5 320 g, K_2O 1,500 g palm^{-1} year^{-1} in addition to FYM or green leaf manure in two equal splits. As, fertilizer application to palms accounts for 45 to 50% of maintenance cost of palms annually, reduction in chemical fertilizers through integrated approach is highly essential . Several field trials in coconuts have shown that the use of chemical fertilizers can be reduced by integrating organic and biological sources of nutrients. The recommended dose of fertilizers can be reduced to 75-50% under various nutrient management practices like recycling of biomass produced in coconut plantations with vermicompost or composting, applying of bio fertilizers like PSB, *Azatobactor*, *Azospirillum* . In the high density multi species cropping system (HDMSCS) at Ambajipeta the total biomass obtained from all the crops was to the tune of 34.5 tonnes/ha/year (7.6 tonnes from coconut, 15.0 tonnes from cocoa, 6.0 tonnes from banana , 3.6 tonnes from pineapple, 1.3 tonnes from elephant foot yam and 1.0 ton from heliconia). The recyclable biomass was converted to vermicompost by using *Eudrilus* sp . About 20.11 tonnes of vermicompost was generated from the collected biomass from one hectare area with a recovery of 58.1% which helped in reducing application of chemical fertilizers to 50% without affecting coconut yield.

Irrigation (Methods of irrigation, Soil moisture conservation & fertigation)

The coconut experiences moisture stress during summer months in most of the coconut growing areas, which adversely affects its productivity. As water is a critical resource to achieve optimum productivity in coconut, adequate irrigation during summer months increase the yield and productivity. The climatic change , irregular rainfall and drought conditions can result in water table decline hence, moisture conservation and improved irrigation practices like drip irrigation plays a key role in sustaining the yield of coconut. Moisture conservation practices for coconut gardens include burial of husk, application of composted coir pith, FYM or farm waste in the coconut basin by digging 20-30 cm trench in the basin area of 1.8 m radius. Surface mulching with coconut leaves or farm waste and sowing of green manure crops in the basins also help in enhancing soil moisture retention. The research results indicated that application of 75 per cent of the recommended dose of fertilizers through drip fertigation was sufficient to produce yield equivalent to 100% of the recommended dose of fertilizers through soil application.

Integrated pest management

Coconut is also depredated by at least 830 insect and mite species, 173 fungi and 78 species of nematodes, significantly affecting the productivity. Among the insect pests rhinoceros beetle *Oryctes rhinoceros* Linnaeus, red palm weevil, *Rhynchophorus ferrugineus* Olivier; black headed caterpillar, *Opisina arenosella* Walker; slug caterpillar *Macroplectra nararia* Moore and eriophyid mite, *Aceria guerreronis* Keifer, are prominent and important. Further, an exotic pest rugose spiraling whitefly, *Aleurodicus rugioperculatus* Martin entered India during 2016. These insect pests damage coconut during different stages and cause economic loss of varying degrees. Basal stem rot, stem bleeding and bud rot are the commonly observed coconut diseases of importance and off late leaf blight caused by *Lasiodiplodia theobromae* incidence is observed in few coconut plantations in East and West Godavari districts . Basal stem rot disease is observed particularly in lighter soils *i.e.*, sandy soil and red soils. In recent years, the disease is also being observed in coastal alluvial soils and in coconut palms on paddy field bunds, fish pond bunds at a significant level. Stem bleeding caused by *Thielaviopsis paradoxa* is also found to occur in all soil types, but more in laterite soils and sandy soils . Bud rot caused by *Phytophthora palmivora* a fatal disease of coconut characterized by the rotting of the terminal bud and surrounding tissues is an important disease especially when incessant rains are being received .

However, in the recent past the use of pesticides for the management of these pests is being discouraged due to their deleterious effects on pollinators and other natural enemies in the coconut ecosystem. Further, spraying of pesticides on coconut palm is not feasible due to its height and intercrops. Under such circumstances, biological control appears to be promising as coconut being a perennial crop with less human interference compared to agricultural crops. For controlling of coconut black headed caterpillar biologically, more than twenty million parasitoids (*Bracon hebetor, Goniozus nephantidis*)were issued to the farmers since inception of lab (1947) . Against another sporadic out break pest slug caterpillar identification and multiplication standardization of potential parasitoid *Pediobius imbrues* again gave impetus to biological control based IPM . Against the recent invasive rugose spiraling whitefly conservation bio control strategy by establishment of potential parasitoid *Encarsia guadeloupae* coupled with augmentative releases of lab reared neuropteran predator *Apertochrysa astur* reiterated confidence in plantation farmers pertaining to biological control

Identification of indicator plants *viz.,* red gram, bengal gram, sesbania and eucalyptus helped in early diagnosis of basal stem rot and standardization of biocontrol based IDM package consisting of field sanitation, raising and ploughing *in situ* green manuring crops like sunhemp, *Sesbania* and *Diancha,* basin irrigation to individual palms and application of talc formulation of *Trichoderma asperellum* (50 g) in combination with 5 kg neem cake/palm/year led to successful containment of this disease in infected gardens. Application of cake formulation of *T. harzianum* or smearing paste of talc formulation of *T. asperellum* on the bleeding patch caused by stem bleeding disease mitigated the disease incidence while application of talc based *Pseudomonas fluorescence* and *T. reesei* in crown region of coconut effectively managed bud rot disease both in nursery and main field.

Effective net working with Rytu Bharosa Kendras in all villages for timely diagnosis of insect pest and diseases , creating a supply chain of quality plant material and formation of domestic quarantine units in important coconut growing districts in view of threat from potential invasive pests like coconut leaf beetle, *Brontispa longissima* and the scale insect, *Aspidiotus rigidus* is the need of the hour so as to sustain the present benefits of technological interventions.

Advances in Agro Technologies for Export Oriented Banana

A. Snehalatha Rani[1], K. Ravindra Kumar[1], G. Ramanandam[1] and L. Naram Naidu[2]

[1] Dr. YSR Horticultural University – Hort. Res. Station, Kovvur, East Godavari District, Andhra Pradesh
[2] Director of Research, Dr. YSR Horticultural University, Venkataramannagudem

Globally Banana is one of the most important fruit crops and is a staple food for more than 500 million people. These are also source of income for many developing countries in the tropics especially African, Asia-Pacific region and Latin American countries. It is produced in the tropical and subtropical regions of mostly the developing countries of Asia Pacific. These are symbol of prosperity and fertility and are popularly referred as 'Kalpatharu'. Among fruits, banana is the most consumed and is highly nutritious fruit crop packed with high dietary fibres, vitamins and minerals. At present, bananas are produced in 135 countries and overseas territories across the tropics and subtropics (FAO) with a total annual world production of 155 million tonnes. Out of which, 120 million tonnes come under desert bananas (75%) and 40 million tonnes under plantains or cooking bananas (25%) were the most produced (US $ 60 billion) and traded (25 million tons worth of US $ 12 billion). International demand for bananas is ever more increasing having lots of scope owing to higher consumer demand for nutritious fruits. There are more than 1000 varieties of bananas produced and consumed locally in the world, but the most commercialized is the Cavendish type banana, which accounts for around 57 per cent of global production and other desert bananas, has only 13 per cent production share. Locally consumed bananas are a staple food in many tropical countries and play a major role in terms of contributing for food security.

India is the top banana producing nation in the world contributing to 19.85 per cent of the total world production. Banana cultivation in India has been transformed due to introduction of Cavendish banana variety Grand Naine, tissue culture plant material production, water management through drip and fertigation. Banana (*Musa* sp.) is the second most important fruit crop in India next to Mango. Its year-round availability, affordability, varietal range, taste, nutritive and medicinal value makes it the favorite fruit among all classes of people. It is the largest produced and maximally consumed amongst the fruits cultivated in India. It is grown in almost all part of the country. In India, 32 million tonnes of banana are being producing from 8,97,760 ha. cultivated area with a productivity of 35.36 t/ha. Out of which 97 per cent is consumed domestically, while 5 lakh MT is lost due to post harvest losses. Though India is the largest producer of banana however, the export of banana is meager. In 2019-20, India exported 1.96 lakh MT valued at Rs. 660 crores to West Asian and North African countries like UAE, Bahrain, Egypt, Saudi Arabia, Qatar and Iran.

In India, Andhra Pradesh is an important banana growing state standing third in area, first in production and fourth in productivity after Madhya Pradesh, Gujarat and Punjab. In Andhra Pradesh, Banana enjoys second position after mango among fruit crops. Despite frequent natural calamities like cyclones, extreme summer temperatures, gales, hail storms etc., area under banana is increasing year after year indicating the economic importance of the crop in the State. It is grown in an area of one lakh hectares with a production of 5003 thousand metric tons. Coastal Andhra Pradesh and Rayalaseema are two important banana growing areas with diverse agro climatic zones. Kadapa, Anantapur, West Godavari, East Godavari, Krishna, Guntur and Vizianagaram are the major banana growing districts in Andhra Pradesh. Grand Naine cultivar currently occupies more than 90% of the banana area in the

Rayalaseema zone, with other desert banana cultivars accounting for the remaining 10%. This region produces high-quality Cavendish bananas that are exported to other Indian mega cities and countries in the Middle East. Polyclonal banana cultivation is prevailing in coastal zone of AP with native banana cultivars like Karpura Chakkera Keli (Poovan) (AAB), Tella Chakkera Keli (AAA), Erra Chakkera Keli (Red banana) (AAA), Martaman (Bengal Amrutapani) (AAA) and Kovvur bontha (ABB).

From Andhra Pradesh, Cavendish banana exports increased from 216 MT in 2016–17 to 45000 MT in 2020–21 with a target of 75000 MT for the current fiscal year. For the last one decade, India has remained as the largest producer of bananas in the world. This enhanced production of is mainly attributed to enhanced area under cultivation, but mainly due to increased productivity per unit area made possible due to the use of tissue culture plants of high yielding superior genotype like Grand Naine for cultivation, integrated nutrient and water management, fertigation, high density planting, rationing and integrated disease management.

Production technology/Agro technology

Export suitable varieties

Among the available banana genotypes, cv. Grand Naine (Pedda paccha arati) is highly suitable for export owing to its high yielding, quality fruits with long shelf life over other cultivars. It is semi-tall with a little more stature than dwarf varieties. The petiole margins are spread out and tinged purple. It is little less susceptible to wind damage. It has a slightly thicker and more rigid bunch stalk, it is a heavy yielder. The fruits are big, slightly angular, and curved. The ribs are not distinct. The rind colour continues to be light green. The pulp is creamy white, soft and buttery. The seed core is prominent. It is suitable for the entire state and occupying the major banana area in the state. It is highly susceptible to *Eumusae leaf spot (*Sigatoka*)*, rhizome rot and immune to panama disease. Each bunch weighs 25-30 kg with 10-11 hands and 130-160 fruits. The duration is 10-11 months and the spacing 1.8 x 1.8m.

Apart from this genotype, there is a good scope for exporting the traditional banana varieties like Karpura Chakkera Keli (Poovan) and Erra Chakkera Keli (Red banana) genotypes in future as they are rich in nutrients with long shelf life.

Cultivation aspects

Production technologies like *viz.* planting time, plant density, planting method, planting material selection and treatment, planting systems, nutrition management, irrigation schedule, weed management, ratoon management and cropping systems are standardized for Grand Naine and other commercial banana cultivars of the state.

- Planting in the month of June is the optimum time for Cavendish cultivars and Tella Chakkerakeli (AAA) banana.
- Plant density

Genotype	Spacing (meters)	No of plants per Ha.
Dwarf Cavendish (AAA)	1.5 x 1.5 m	5100 plants ha^{-1}
Grand Naine (AAA)	1.8 x 1.8 m	3086 plants ha^{-1}
Tella Chakkerakeli (AAA)	1.8 x 1.8 m	3086 plants ha^{-1}
Amritapani/Martaman	2.0 x 2.0 m	2500 plants ha^{1}
Karpura Chakkerakeli (AAB)	2.0 x 2.0 m	2500 plants ha^{1}

- **High density planting system (paired row system of planting) for important commercial banana cultivars to get higher returns over conventional system of planting was standardized.**

Robusta (AAA)	**1.2 x 1.2 x 2.0 m**	**5200 Suckers ha^{-1}**
Tella Chakkerakeli (AAA)	**1.2 x 1.2 x 2.0 m**	**5200 Suckers ha^{-1}**
Dwarf Cavendish (AAA)	**1.0 x 1.0 x 1.8 m**	**7440 Suckers ha^{-1}**

Tissue culture plants as source of planting material

- Standardized the tissue culture protocols for Grand Naine and other traditional banana cultivars of state. Tissue culture plants were found to be superior over traditional planting material with respect to quality, disease resistance and enhanced yields in all the cultivated banana genotypes. Increase in bunch weight was 65% in banana cv. Grand naine. The significant increase in productivity also observed in traditional varieties like Karpura Chakkerakeli, Tella Chakkerakeli and Redbanana by using tissue culture plants over suckers as planting material. Moreover, tissue culture plants are uniform in nature, precautious in bearing and free from threatening diseases like bacterial rhizome rot, fusarium wilt and viruses.

Nutrient management

- **Optimum nutrient requirement for commercial cultivars of the state was standardized.**

Cultivar	Nutrient (g) plant^{-1} crop cycle^{-1}			Splits	Interval (days)
	Nitrogen	Phosphorus	Potassium		
Karpura Chakkerakeli	200	50	200	4	45
Robusta	200	50	200	4	40
Dwarf Cavendish	200	50	200	4	40
Tella Chakkerakeli	250	50	250	5	35

- **Phosphorous in the form of single super phosphate as basal incorporation in to the planting pit was found to be ideal. Application of nitrogen and potassium in vegetative phase was found beneficial than application in post shooting stage.**
- 80 per cent of recommended dose of nitrogen and potassium were found sufficient for raising ratoon crop.
- **Enhancing input use efficiency in banana:** Drip irrigation (80% ER) + fertigation (based on STCR equation developed at NRCB - 75% of worked out NPK with 80% ER) + micronutrient foliar spray (Banana Shakti 2%) + SOP bunch spray (2%) was found to be the best with respect to bunch weight, yield, quality and B:C ratio in banana cv Grand Naine. Precise application of nutrients in grand vegetative phase yielded highest productivity with export quality produce in Grand Naine cultivar.

Water management

- Estimated that 30% to 50% of water can be saved when the Cavendish group banana (AAA) was irrigated through drip system at 100% CPE depending on season and cycle of the crop.

Fertigation

- Fertilizer use efficiency is more with increased number of splits.
- Under fertigation, for heavy soils 50% of RDF and for light soils 75% of RDF is sufficient to harvest higher yield and also reduces the crop cycle by 20 days.
- Under this 80% of the N&K fertilizers should be given in 22 split doses before shooting at weekly intervals starting from 3rd week after planting to 24th week after planting.
- Remaining 20% of the N& K fertilizers should be given after shooting in 5 splits at weekly intervals from 31st to 35th week after planting.

Fertigation schedule for tissue culture banana

Days after planting	Heavy soils	Light soils
3rd to 6th week at 3 days interval	4 g Urea + 3 g MOP/plant	4 g Urea + 3 g MOP/plant
7th to 14th week at 3 days interval	4.7 g Urea + 4 g MOP/plant	8.3 g Urea + 6.9 g MOP/plant
15th to 24th week at 3 days interval	5 g Urea + 4.5 g MOP/plant	9 g Urea + 7.5 g MOP/plant
* 31st to 35th week at 3 days interval	4.7 g Urea + 4 g MOP/plant	8.8 g Urea + 7.1 g MOP/plant
* Post shooting application		

Micronutrient Spray

- Micronutrient mixture @ 5 kg ha^{-1} should be applied through drip starting from 2nd, 4th and 6th month after planting. A foliar spray of Arka banana special @ 4 g l^{-1}, Banana Shakti @ 5 g l^{-1} along with KNo3 @ 5 g l^{-1} should be given at 15 days interval especially during December to February months to get proper bunch filling.

Bunch management

a. Bud injection

- Incidence of banana flower thrips at inflorescence emergence stage cause smoky or red discoloration between individual fingers. The skin becomes reddish brown, roughened and dull in appearance, superficial cracks appear in the discolored skin. The fruits may also split.
- Need to prevent the thrips incidence for producing export quality bananas. Inject Imidacloprid (0.6 ml L^{-1}) @ 1 ml directly into the upright bell as it emerges from the throat of banana plant.
- Make the bell injection at 30° angle from the top one third of the emerging bell while the newly emerged bells are still upright in position

b. Bunch sprays

- The requirement of potash is very high during bunch formation, hands opening and finger developmental stages. Bunch spraying is highly essential to meet the potash requirement and to produce export quality bunches. Spraying bunches with 1.0% K_2SO_4 or 0.5% KNo3 at 5 and 20 days after last hand opening can improve the fruit grade and quality of banana.

- Fruits ripen prematurely because of the very low potassium uptake from the soil during the winter season. To mitigate this, spraying bunches with Potassium hydrogen ortho phosphate @ 5 g l^{-1} @ 2-3 times in weekly or ten days interval is recommended.

c. Bunch sleeves

- Covering bunches with 100 guage white (transparent) polyethylene bags with 2 per cent ventilation at the time of last hand emergence improved finger length and finger girth which ultimately reflected in bunch weight increase (16.0%).
- Bunch covering resulted in harvest of attractive light green lustrous fruits without any bruises and signs of biological infestation.
- Covering the bunches with 100 guage blue color polyethylene bags with 2 per cent ventilation is highly recommended during winter season for the early bunch harvesting and production of export quality fruits.
- In recent years, polypropylene bunch covers for bananas have also become more affordable and useful in generating bananas of an export-quality.

d. Other management practices

- There should be at least 12-13 healthy green leaves remaining on the plant at flower initiation stage to ensures maximum bunch development.
- The dry and diseased leaves should be removed and destroyed regularly.
- Soil mounding is done in eighth month and a follower is left for ratoon.
- At flowering the plants are propped up with bamboos to protect from strong winds or gales in coastal region.
- After flowering is completed, the male flower bud should be removed (Denavelling).
- An insecticidal cum fungicidal spray at this stage ensures good quality of fruits.
- The flag leaf should be bent on the peduncle and tied to protect from sun scorching.
- Additional yield of 18-20% can be obtained by feeding the bunch end stalk with 500 g fresh cow dung + 7.5 g Sulphate of potash + 7.5 g Urea in 60º angle.
- Removal of dried floral bracts and floral ruminants a week after opening of the last hand to avoid ‘finger rot disease’ and to give attractive appearance to the produce.
- One or two small bottom hands should be removed from the bunch in order to facilitate uniform bunch development. Sometimes, removal of weak and improper shaped fingers from hands can improve the quality of fruits.

Advances in Plant protection technologies

- Planting disease-free materials preferably tissue culture plantlets, avoiding ill-drained soils, clean cultivation and growing resistant varieties to be followed for obtaining quality produce.
- The geographical distribution and time occurrence of diseases in different banana growing areas of Andhra Pradesh revealed that panama wilt incidence is high in the coastal districts where

cultivar Amritapani belonging to the susceptible Silk sub group are cultivated. Sigatoka and other leaf spots are a major constraint in susceptible Cavendish sub group cultivars, Robusta, Grand Naine and Dwarf Cavendish particularly in the rainy season. Viral diseases *viz*; bunchy top, bract mosaic, infectious chlorosis and banana streak virus are also prevalent in the state.

- Banana accessions of different genomes and sub groups were screened for their reaction to diseases. Accessions belonging to Ney poovan (AB), Silk (AAB), Pisang Awak (ABB) and Bluggoe (ABB) were susceptible to *Fusarium* wilt. The FHIA hybrids and other accessions *viz.* Yangambi km5, Pisang Ceylon, Williams, GCTCV 119 and GCTCV 215, which were screened as a part of the International Musa Testing Programme (IMTP), were resistant to *Fusarium* wilt.
- Cultivars of Cavendish sub group were susceptible to Eumusae (Sigatoka) and other leaf spots while diploid AA cultivars, Sanna Chenkadali, Calcutta 4, Pisang Mas, Cultivar Rose, Pisang Lilin were highly resistant.
- Tella Chakkerakeli (AAA), Culinary varieties (ABB), Cavendish cultivars and Pisang Lilin (AA) were susceptible to *Erwinia* soft rot. Virus diseases were observed in all the accessions.
- Correlations between weather and major banana diseases in important commercial cultivars of the state revealed a highly significant positive correlation between maximum temperature and rhizome rot caused by *Erwinia carotovora carotovora* in Cavendish Cultivars while a significant positive correlation exits between relative humidity rainfall and number of rainy days and rhizome rot caused by *E. chrysanthemi* in Pisang Awak cultivars.
- Significant positive correlation between weather factors viz. rainfall, number of rainy days, and relative humidity, and Sigatoka leaf spot intensity was observed. Significant negative correlation between temperature and bract mosaic incidence was observed in all the commercial banana varieties.
- *Eumusae* (Sigatoka) leaf spot is the most prevalent foliar disease of banana particularly in rainy season.
  - Grand naine is highly susceptible to sigatoka leaf spot disease
  - Incidence of sigatoka disease is more during rainy season. Prophylactic management measures should be taken care before rainy season and curative management measures to be followed after the incidence of the disease
  - Recommended spacing (1.8 × 1.8 m) to be followed as closer spacing leads to changes in microenvironment and thereby favours leaf spot pathogen
  - Proper drainage facilities to be taken care
  - Application of recommended dose nitrogen and potassium fertilizers (435 g urea and 345 g potash / plant) for tissue culture plants in nine split doses in heavy soils and twelve split doses for light soils
  - Desuckering at frequent intervals, field sanitation and weed management
  - Prophylactic spray with Mancozeb (2.5 g/liter of water) before rainy season
  - Curative management: After the appearance of the disease, spraying of Propiconazole (1ml/liter of water) along with 10 ml of mineral oil three times at 25 days interval. Remove the dried and infected leaves before spraying with the chemical

- Management of *Eumusae* leaf spot disease of banana under high disease pressure: The following spray schedule with alternation of chemicals alone or alternation of chemicals along with mineral oil (0.1%) was developed. Spray schedule: First spray of 0.1% of propiconazole after the onset of disease followed by second spray of 0.1% of combination product [carbendazim (12%) + mancozeb (63%)], followed by a third spray of 0.14% of combination product [trifloxystrobin (25%) + tebuconazole (50%)] followed by fourth spray of 0.1% of difenoconazole. This should be followed by repeated first, second and third sprays at 25 days interval each. A total of five to seven sprays may be imposed at 25 days interval based on the severity of the Eumusae leaf spot disease in the field.

- Viral diseases in particular, Banana bract mosaic virus (BBrMV) reduce both quantity and quality of the products. Effect of Banana bract mosaic and Banana Streak Virus on commercial cultivars revealed that the yield loss due to BBrMV in terms of bunch weight was up to 47% in Kovvur Bontha, 44% in Robusta and 54% in Dwarf Cavendish.
- *Pratylenchus*, *Radopholus*, *Meloidogyne*, *Hoplolaimus* and *Helicotylenchus* are the plant parasitic nematode genera found in banana. Application of carbofuran (40g/ plant) or cartap hydrochloride (10g/ plant) at the time of planting reduces the losses caused by nematodes in banana.
- **Postharvest disease management in banana**: Anthracnose, Crown rot and cigar-end rot caused by *Colletotrichum musae, Fusarium* sp. and *Botryodiplodia theobromae* are the major diseases observed on the banana fruits kept for storage under Andhra Pradesh conditions. Non-chemical management studies of postharvest diseases of banana revealed that dipping of hands in 1% potassium aluminium sulphate (alum) solution followed by packing in low density polythene (150 gauge) with ethylene absorbent immediately after harvest recorded an extended green life and total shelf life for a period of 6 days with no disease incidence and severity.

Commercial dessert varieties of banana from Andhra Pradesh


Grand Naine


Karpura Chakkerakeli


Tella Chakkerakeli


Red banana
(Erra Chakkerakeli)

Agritourism Opportunities and Challenges in High Altitude Tribal Zone of Andhra Pradesh

M. Suresh Kumar

Associate Director of Research, Regional Agricultural Research Station, Chintapalle, ANGRAU

Agricultural Tourism is the holidays concept of people visiting a working farm or any agricultural, horticultural or agribusiness operations for the purpose of enjoyment, education, or active involvement in the activities of the farm or operation. Stated more technically, agritourism can be defined as a form of commercial enterprise that links agricultural production and/or processing with tourism to attract visitors onto a farm, ranch, or other agricultural business for the purposes of entertaining and/or educating the visitors while generating income for the farm, ranch, or business owner. In crisp, Agritourism could be thought of as the crossroads of tourism and agriculture. World Tourism Organization (1998) defines Agritourism as "activity involves accommodation being offered in the farmhouse or in a separate guesthouse, providing meals and organizing guests' activities in the observation and participation in the farming operations.". The term "agritourism" is often used interchangeably with "agritourism," "agrotourism," "farm tourism," "agricultural tourism," or "agritainment.".

Advantages

Agritourism is one of the emerging areas of entrepreneurial engagements for the agriculturalists to cope with the economic risks posed by climate change. It essentially involves diversifying income streams from agricultural activities and the associated value chains. Agritourism presents a unique opportunity to combine aspects of the tourism and agriculture industries to provide a number of financial, educational, and social benefits to tourists, producers, and communities. It brings major primary sector agriculture closer to major service sector tourism. This convergence is expected to create win-win situation for both the sectors of Agriculture and Tourism as Tourism sector has potential to enlarge and Agriculture sector has the capacity to absorb expansion in tourism Sector. Agritourism helps preserve rural lifestyles and landscape and also offers the opportunity to provide "sustainable" or "green" tourism.

Features

Organic agriculture is a cultural evolution that finds its origins in an environmentalist culture. Agritourism gives producers an opportunity to generate additional income and an avenue for direct marketing to consumers. It enhances the tourism industry by increasing the volume of visitors to an area and the length of their stay. Agritourism also provides communities with the potential to increase their local tax bases and new employment opportunities. Additionally, agritourism provides educational opportunities to the public, helps to preserve agricultural lands, and allows states to develop business enterprises. The Agri tourism project provides edutainment to the visitors, showing the concepts of agriculture, bringing the future generations close to nature, giving hands-on experience on farming related activities. Agri-tourism makes tourists live life like a villager, right from milking the cow, plough the field, bathing in a well, to climb a tree and plucking fruits from trees. These places offer authentic village and farm life by providing interactive experience of rural life. Fresh air is all we seek today and these are places where we can repair our polluted lungs. Agritourism is gaining the most important traction in the farmer community, as it not only offers added income to the farmers along with their farm production actions but also better sustainability across the globe. Farm tourism has huge potential to provide good business opportunities to the farmers and also offer cost-effective and family-oriented recreation surroundings, which is driving the market growth.

Basic Principles & Components

Agritourism should ensure the following principles like, to have something for the visitors to see, in the form of natural resources, tradition, culture and values of rural people, fairs and festivals, etc., to have something for the visitors to do, in which they can participate and enjoy, like horse-riding, milking cattle, picking fruits, etc and to have something for the visitors to buy, like on-farm agricultural products, rural crafts, etc. Regardless of the exact definition or terminology, any definition of agritourism should include the following factors viz., outdoor recreation, educational experiences, entertainment (harvest festivals), hospitality services (farm stays, guided tours or outfitter services) and on-farm direct sales.

Agri-Tourism Model in HAT Zone

In a move to strike a balance between empowering farming communities of Eastern Ghats and improving rural economy, Acharya N. G. Ranga Agricultural University (ANGRAU) - Regional Agricultural Research Station (RARS), Chintapalle, is focusing on promoting agritourism in the Agency areas on a large scale. RARS-Chintapalle have initiated the agritourism in September, 2022 to attract visitors who want to deter away from the maddening crowd. Probably, it is first time in Andhra Pradesh (A.P) that agritourism concept has been introduced by RARS-Chintapalle to serve the dual purpose of supporting income of farmers and creating novel tourism forms for tourists contributing to economic, social, and environmental dimensions of sustainability with the objective of giving a fresh feel of soil, crop and ecosystem to the visitors. Slowly but surely, the agritourism will become a game changer for the tribal youth and also for the tribal farmers. The agritourism will create a marketing facility in the tribal pockets and the tribal farmers would realize remunerative price for their organic produce. As a first step towards boosting agritourism, gardens with Gladiolus, Tulips, China aster, Marigold, and Oriental and Asiatic liliums were grown at RARS. Crossing three different stages of research, the flower crops, including Gladiolus, Lilium and China Aster, are now grown in Lambasingi farmlands as well. As a part of its research and extension activities carried out in Andhra Pradesh, ANGRAU has been rendering service to the tribal farming communities extending along 37 agency mandals spread over Alluri Seetharamaraju, Parvathipuram Manyam and Srikakulam districts of the state. From cultivating a few exotic varieties of flower crops in the station greenhouse on an experimental basis last year, RARS has come a long way in taking the floriculture way forward to push agritourism up a notch higher, connecting tourists with a slice of tribal life, RARS intends to step up floriculture beyond its station campus and spread its wings to the neighbouring farmlands.

Components of the Proposed Model

The university is keen on taking the agritourism to the next level by spearheading farm-friendly initiatives such as conservation of medicinal herbs, integrated farming system, organic farming, millet museum, honey extraction, tractor driving and bullock cart riding, among a plenty other activity. The idea is to offer the visitors glimpses of agrarian lifestyle, culture, and heritage with its abundance of natural resources. Under this concept, tourists shall be taken to a farm. They will be allowed to try hands on farming. Guests will be served local cuisine. Its objective is to create a homely feel in natural settings,". A group of tourists (mostly families of 10 to 12 members can stay at RARS Chintapalle. On average during the weekends, over 100 people visit RARS for agritourism, and soon school children, and students of various colleges will visit to explore agritourism. The agritourism project here provides edutainment to the visitors (family), showing the concepts of agriculture, bringing the future generations close to nature, giving hands-on experience on farming related activities, showing organic cultivation of various crops, floriculture with exotic flowers, conservation of medicinal and aromatic plants, integrated farming systems, millet museum, and many more.

Challenges

Challenges are divided into five categories, namely financial, human resource, technical, policy challenges and legal issues and are presenter here under.

Financial Challenges

a) Lack of awareness about credit and subsidy facilities for various components

b) No insurance coverage

c) Maintenance charges

d) High cost of land development and initial investment

e) High cost of labour

f) Non-availability of tourists at vacation time (seasonality of tourists)

g) Lack of government support

h) Non-willingness of the tourists to purchase farm products.

Technical challenges

a) Limited and irregular power supply

b) Inadequate supply of inputs

c) Unfavourable weather conditions

d) Insufficient literature for agritourism practice

Human Resource Challenges

a) Weak communication skills of staff

b) Lack of experience of farmers in the running of a tourism business

c) Lack of knowledge, expertise and training in the tourism field

d) Limited marketing channels and linkages

e) Necessity to develop new skills in order to manage the tourists and their expectations

f) Lack of organised effort like Farmer organisations

g) Lack of commercial approach like other tourism venture

Policy level Challenges

a) Lack of transportation to interior rural places

b) No specific policy for promotion of agritourism

c) Complexity in getting license from Govt

d) Lack of training in hospitality and management

Further Scope

Within ANGRAU

The university can envisage a comprehensive plan to convert all its research stations, Colleges and Extension centers into Agro tourism spots to attract tourists, youth interested to know about Agricultural & allied activities. This programme could be integrated with GOI -ICAR programmes for attracting youth towards taking up agriculture as a profession.

With in Andhra Pradesh

ANGRAU could hand hold all the ministries of Government of Andhra Pradesh to convert all its public offices, premises into agritourism spots to enhance the revenue besides greenification and beautification of the Government assets.

Farming Community

Government could encourage the small and marginal farmers to convert their holdings tourist friendly on collective basis. The central government scheme on FPOs can be sufficiently modified with the help of NABARD to promote these activities at farmer and community level on a mission mode

Strategies for Promotion

The strategies are always long-term oriented goals for any organization or an individual.

a) Policy initiatives Price policy mechanism

b) Subsidy for start-up like agritourism

c) New training centers at nearby agricultural institutions

d) Research and development initiatives

e) Market survey in the urban areas identify potential consumers

f) Marketing initiatives like promotion of direct marketing and forward marketing of the produce

g) Creation of specialized brand for the produce and specialized market for the produce

h) Standardization of designs and structure of low cost agritourism initiative for different agro climatic regions of the country

i) Appropriate selection of location and site for agritourism initiative

j) Farmer level initiatives like Cluster and cooperative based approach in operation and development of agritourism

k) Timely availability of quality inputs

l) Regular power supply (three phase)

m) Reducing the high initial investment through introducing low-cost construction materials like locally available vernacular materials

n) Thorough intense research and case studies

o) Availability of raw material of required quality at local market

p) Creation of separate cargo flights for national and international markets to export the produce

q) Improving communication skills and authentic rural hospitality

r) Public - Private partnership

Conclusions

Agritourism as "activity involves accommodation being offered in the farmhouse or in a separate guesthouse, providing meals and organizing guests' activities in the observation and participation in the farming operations. Agritourism is one of the emerging areas of entrepreneurial engagements for the agriculturalists to cope with the economic risks posed by climate change. Regardless of the exact definition or terminology, any definition of agritourism should include the following factors viz., outdoor recreation, educational experiences, entertainment (harvest festivals), hospitality services (farm stays, guided tours or outfitter services) and On-farm direct sales. In a move to strike a balance between empowering farming communities of Eastern Ghats and improving rural economy, Acharya N. G. Ranga Agricultural University (ANGRAU) - Regional Agricultural Research Station (RARS), Chintapalle, is focusing on promoting agritourism in the Agency areas on a large scale. The pilot model implemented included conservation of medicinal herbs, integrated farming system, organic farming, millet museum, honey extraction, tractor driving and bullock cart riding, among a plenty other activity. The agritourism project here provides edutainment to the visitors (family), showing the concepts of agriculture, bringing the future generations close to nature, giving hands-on experience on farming related activities, showing organic cultivation of various crops, floriculture with exotic flowers, conservation of medicinal and aromatic plants, integrated farming systems, millet museum, and many more. Financial, Technical, HR and Policy level challenges should be addressed to achieve the future scope of all premises of ANGRAU, Universities Research centers and all other Public assets to be re oriented to become Agro tourism centers to attract visitors so as to enhance their revenues through strategies such as Price policy, Subsidy, training, R&D, Market survey, Branding, Public - Private partnership, Aviation facilities *etc.*

Role of Digital Tools for Sustainability in Coastal Ecosystem

Hema Lingireddy, Pranuthi Gogumalla, Jameeruddin Shaik and Srikanth Rupavatharam

International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Hyderabad, India 502324
Corresponding author: r.srikanth@icrisat.org

Over 40 per cent of the world's population live in coastal areas or within 100 kilometers of the coast, among highly productive deltas, coral reefs, mangrove biomes, and the nearby land-based estuaries emphasizes the need for identifying challenges for improving livelihood security in coastal ecosystems (Neumann *et al.,* 2015). Whereas, the Indian coastline accounts for 5,422 km excluding islands comprises of 8 states and 3 union territories (Velmurugan *et al.,* 2017). Many people in these areas make a living from natural resources, such as farming and fishing. The major agricultural crops grown in the region are rice, banana, cashew nut, areca nut, rubber, betel nut, pulses, spices, vegetables, sugarcane, groundnut and pearl millet, etc (Ramesh *et al.,* 2010). However, coastal agriculture is extremely vulnerable and less stable than upland agriculture because of fluctuations in salinity, tidal processes, water stressors, and waterlogging on a regular basis (Awal M., 2014). In addition to these, coastal areas are susceptible to a wide variety of climate-related risks e.g., rising flood levels, storm surges, rapid coastline erosion, saline intrusion, and rising surface temperatures which may diminish coastal socioeconomic activities such as agriculture, property, coastal habitats, tourism, recreation, transportation, industry, and port operations (Paice & Chambers 2016). The COP26 conference issued a serious warning about the vulnerability of coastal regions to global warming because the enormous concentrations of excess heat stored in the oceans (90%) as compared to the relatively low concentrations in the atmosphere (1%) and the summit also emphasized the need for strengthening ocean action to combat the effects.

Digital technologies include electronic devices, tools, resources and systems that store, generate and process data for user needs. Some of them include social media, games, smart phone applications etc. Advent of smart phone penetration in India has impacted uses of digital applications by farmers in remote India. Digital technologies have the potential to deliver sustainable solutions to address the challenges posed by climate change (George *et al.*, 2021).

Coastal communities experience challenges as a result of climate change cand be mitigated with the use of digital technology. Digital tools that can track weather, sea levels, crop phenology, plant health, and other environmental factors that affect coastal agriculture using satellites and unmanned areal vehicles. There are numerous Internet of Things (IoT) sensors positioned to monitor and support decisions on irrigation and crop growth. Artificial Intelligence (AI) based image recognition technology is also used for the detection of pests and diseases. Digital tools guided by GPS in farm machinery, sensors, and automated weather stations can optimize irrigation, fertilization, and other farming practices in order to improve sustainability and resource use efficiency. Moreover, automated machinery can ensure time and labour-use efficiency. Digital technologies embedding predictive models, big data analytics and cloud computing can be used to forecast weather patterns and aid as early warning systems for events like floods, storms, sea level rise, etc. These technologies can also enable the optimization of farm operations by making more informed decisions about when to plant, harvest, and sell their produce. Farmers, scientists, and other coastal agricultural stakeholders may use digital tools like online platforms, mobile applications, etc. to provide advisories, communicate and collaborate for obtaining innovative solutions for coastal crop management.

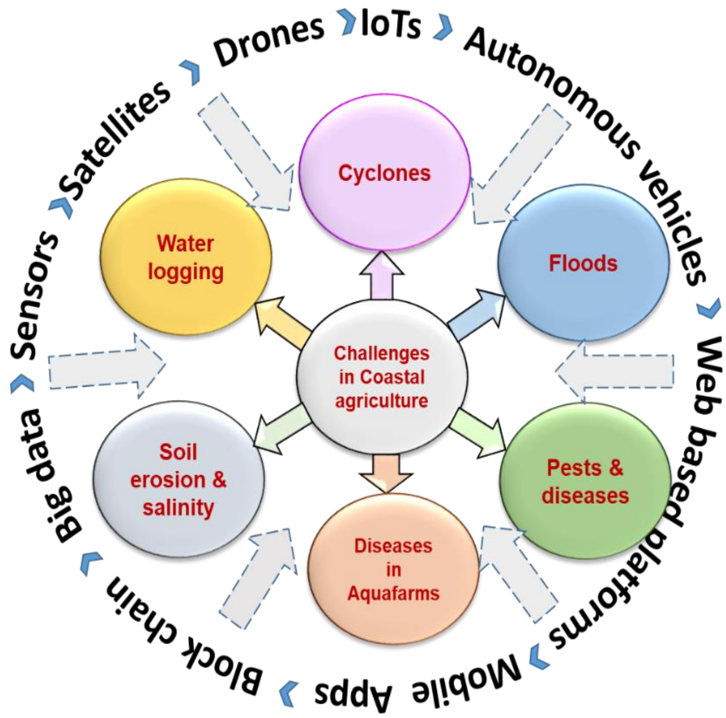

Fig. 1. Figure representing possible digital tools for addressing challenges in coastal agriculture

Adoption of digital technology by coastal farmers can increase the longevity and profitability of their farms, by allowing them to better meet the growing demand for healthy, locally-grown food. However, there is no universal digital tool that can handle everything and it would be very expensive to use every possible component, so it's important to select a tool or a set of tools that not only meet the requirement but are also compatible and cost-effective.

Digital tools have been categorized based on their application in coastal ecosystems

1. Soil Health Management

Soil problems in coastal ecosystem include soil salinity, erosion, nutrient leaching, shallow water table, poor water holding capacity, and flooding. Among these, soil salinity is the primary cause of low crop yields in the ecosystem (Ray *et al.*, 2014). Bashir *et al.* (2022) stated that Internet of Things-assisted salinity mapping, where salinity is characterized in terms of EC, pH, and total dissolved salts, is a low-cost, easily transportable technology that can be used for site-specific treatments and soil zones management in salty soils. Soil moisture and nutrient content can also be predicted using soil sensors (Shamshiri *et al.*, 2022). A study conducted by Asfaw *et al.*, (2018a) mentions the advantages of combining the Landsat-based salinity index with GIS in mapping spatial variations. Models of soil salinity prediction can also be integrated for more precise control of salinity. Moreover, soil salinity can be predicted globally using a combination of NIR- spectroscopy, climate data, and advanced machine learning algorithms (Zhou *et al.*, 2022). Simarmata *et al.*, (2020) concluded that variable rate and site-specific nutrient management techniques can aid in the efficient usage of nutrients. Apart from these, several web-based platforms and android applications are available in market place which can promote soil health management in coastal ecosystems are listed below (Table 1)

Table 1. Digital tools available for Soil Health Management

Name	Type	Features
OpenTEAM	Web-based platform	A farmer-driven community for digital technology-based soil health management & knowledge-sharing
SLUSI web portal	Web-based platform	Provides soil resource maps and uploads soil survey information too online
Jaivik kheti portal	Web-based platform	A knowledge-sharing platform related to organic farming
RiceNxpert	Mobile App	A Smart Nitrogen monitoring & recommendation application
Soil Nutrient Manager	Mobile App	Recommends optimum fertilizer requirement based on soil fertility status and crop type, to achieve higher yields
Plantix	Mobile App	AI-based application for detecting nutrient deficiency as well as for nutrient management advisory
Soil Health Maps	Web-based platform	Provides soil health maps related to nutrient content in Indian soils
Agrocares	Web-based platform	Performs real-time soil fertility monitoring
Fertilizer Optimizer	Application	Provides the most profitable combination of fertilizers as well as advisory on crop and site specific nutrient application rates

2. Climate Smart agriculture

Extreme weather events such as cyclones, floods, and tsunamis pose a risk to agricultural operations in coastal areas. In addition, agricultural production may be hampered by the submergence of crops due to rise in sea level. Use of digital tools can improve the capacity of farmers to be prepared for risks and respond to unpredictable weather events. Satellite-based rainfall estimates, GIS, Information and Communication Technologies (ICTs), and wireless sensor networks can help in detecting climatic shifts that may lead to disasters like floods and tsunamis. According to Munawar *et al.*, (2022) remote sensing technology can be utilised for a variety of purposes, including risk modelling, early warning, rainfall mapping, monitoring, and spatial planning. Use of sophisticated sensors with more bands and greater spatiotemporal resolutions can enable accurate detection and damage assessment of flood events (Ban *et al.*, 2017). Whereas, LiDAR time-series data can be used to evaluate and estimate coastal erosion (Sesli & Caniberk, 2015). Broadband technology advancements offer accuracy, reliability, and adaptability in climate change mitigation, adoption, and monitoring (Shafiq *et al.*, 2014). The World Meteorological Organization (WMO) suggested that forecasters can profit from Next-generation forecast workstations by adopting improved visualization and information-processing capabilities. The apps and websites described in Table 2.

Table 2. Digital tools for Weather based advisories

Name	Type	Features
Meghdoot	Mobile App	Every Tuesday and Friday, the Agro Met Field Units (AMFU) release crop-specific weather forecasts and advisories that are contextualized by the district. This app puts all of this data in the hands of farmers without any extra work.
AWIPS	Web-based platform	Meteorological display and analysis package developed to aid forecasters, this makes use of data from the National Oceanic and Atmospheric Administration (NOAA).
MAUSAM	Mobile App	Users can view current conditions, future forecasts, and radar images, as well as receive advance warnings of severe weather.
Skymet Weather	Web-based platform	Provides live weather news & updates
Indian Satellite Weather	Mobile App	Provides weather news, podcasts, and satellite maps,
SAFAR-India	Web-based platform	This integrates Air Quality, Health Advisories, and Food Security in a web portal
Kerala Rain	Mobile App	This is the first weather app to focus exclusively on the weather, rains, and floods in Kerala
Sky-Mitra	Mobile App	An interactive app that sends up-to-the-minute weather updates and forecasts to farmers.
Fasal Salah Agriculture App	Mobile App	Provides highly personalized farmer specific crop weather advisories for Indian farmers.
Open weather	Web-based platform	A platform that provides timely weather forecasts precisely

3. Crop Production and Protection

The higher relative humidity in coastal areas increases the pest and disease incidence making coastal farming less profitable than in plains. Water stress assessment, crop monitoring, nutrient management, pest and disease management, etc. are some of the applications of satellite and drone-based imagery (Sishodia *et al.,* 2020). Precision farming utilizes sensor-based or map-based variable rate technology to ensure that chemicals are applied precisely at the right location and time (Grisso *et al.*, 2011). Robotics and automated machinery can be used to perform tasks such as weeding, spraying, harvesting, etc., without human intervention. Besides these, agrochemicals can be sprayed using unmanned aerial vehicles (Mogili and Deepak., 2018). Moreover, with an IoT systems like

AEROFARM, Thailand farmers monitor soil moisture, nutrient content, and pH to determine how much water their rice fields actually need, which varies depending on factors like temperature and crop type (Kularbphettong *et al.,* 2019). A detailed list of mobile apps and digital platforms that provide crop information and support enhancement of production in coastal ecosystems are in Table 3.

Table 3. Digital tools for Crop Production

Name	Type	Features
AutoMonPH	Web-based platform	An IoT-based decision support tool for real time monitoring, irrigation scheduling and carbon footprint monitoring
Rice Xpert	Mobile App	Offers real-time information to farmers on insect pests, nutrients, weeds, nematodes and disease-related challenges, rice varieties for various ecosystems and farm equipment for various field and post-harvest processes
Rice Crop Manager (RCM)	Web-based platform	Delivers field-specific information on crop and nutrient management to increase yields and income of rice farmers
Rice Telugu	Mobile App	It's a knowledge-repository that provides comprehensive information on agronomic activities including planting, variety selection, disease/pest management, micronutrient management, irrigation, and more in the Telugu language
Rice Knowledge Management Portal (RKMP)	Web-based platform	Provides one-stop shop for reliable, validated, timely, and contextual rice information
Kalgudi	Web-based platform & mobile application	A digital convergence platform & application that enables all ecosystem players to share their needs, ask & answer questions, receive news & information like farm advisories, market linkages, market prices, etc
DeHaat	Web-based platform & Mobile App	Onestop platform & mobile application that provides multiple services, including frequent crop reminders, voice calls in regional languages, crop advisories, weather reports, local mandi rates, etc.
Vyavasayam Telugu Agriculture	Mobile App	A knowledge-repository that provides information about various agriculture crops in Telugu
NaPanta-	Mobile App	Help farmers in their own language with everything from soil preparation to market linkages
Pantala Yajamanyam	Mobile App	A knowledge-repository on Rice, maize, pigeon pea, soybean, and cotton crop management information in Telugu
IFFCO Kisan-Agriculture	Mobile App	Provides customized advisory services with more visual content to be useful for the farmers

Apart from the above-mentioned tools, there are digital tools that support in Integrated Pest Management for sustaining coastal ecosystems as in Table 4. Among them, applications like Plantix, Agrio, Nuru, etc., uses AI-based image recognition technology to identify plant pests and diseases. Whereas, few applications maintain a knowledge repository for the identification and management of symptoms.

Table 4. Digital tools for Crop Protection

Name	Type	Features
Plantix	Mobile App	AI-based image recognition app for pest and disease identification, also suggests proven management practices for specific symptom
Rice Doctor	Mobile App	Interactive tool which helps in diagnosis and management of pests and diseases in Rice
Mobile Rice IPM	Mobile App	A knowledge repository type application which provides critical information on important pests, diseases, weeds, and nutritional deficiency in rice crops, as well as their control measures
Rice Pest Lab	Mobile App	Includes features like Pest Screening, Pest Monitoring, Pest Diversity, Pest Loss Assessment and Pesticide Evaluation
Rice IFC	Mobile App	This app has features on Rice Insecticide and Fungicide calculation
Rice IPM	Mobile App	R-IPM is a holistic plant health management that combines tools/ methods/ practices for economic management of pests & diseases
Rice Expert System	Mobile App	It is an advisory system for dissemination of up-to-date scientific knowledge of plant protection in an easily understandable form. It provides recommendations even in the absence of expert
Crop Doctor	Mobile App	It disseminates information on plant disease, insect, and nutrient deficiency to the farmers
Agrio	Mobile App	Provides AI-based solutions that helps growers and crop advisors to forecast, identify, and treat plant diseases, pests, and nutrient deficiencies
PlantVillage Nuru	Mobile App	Application that uses a digital assistant to help farmers diagnose crop disease in the field, without an internet connection.

4. Aquaculture

Adoption of digital technologies in Aquafarms ensures the industry's sustainability and productivity. Digital agriculture advancements such as drones, sensors, IoTs, AI, and block chain technology can assist in addressing the growing demand for fish and other aquatic products. More efficient and accurate methods for monitoring fish behaviour, fish farm health, illegal fishing surveillance, water quality assessment are facilitated by unmanned vehicle technologies (Ubina *et al.*, 2022). Additionally, the remotely operated vehicles can be utilised to quickly inspect nets. On the other hand, sensors and Internet of Things technology can be used to analyse fish appetite, fish illness monitoring and so on. Other digital tools related to Aquaframing are listed in Table 5.

Table 5. Digital tools for Aquaculture

Name	**Type**	**Features**
Aquaconnect Farmer	Mobile app	Helps aquaculture farmers in calculation of optimum feed ratio, disease prediction, water quality monitoring, and also provides current market prices
Aquanetix	Mobile App & Web-based platform	Provides complete solutions for optimizing the management of Aquafarms
AquaManager	Web-based platform	Provides information on integrated hatchery management
Smart Water Planet	Web-based platform	Provides feed recommendations and suggestions on optimum time for harvesting and selling
Aquabyte	Web-based platform	Aids in automatic lice counting, welfare scouting, and biomass control

5. Market Linkages

Marketing is one of the major issues in coastal areas due to unpredicticable weather events, poor transportation facilities, etc. However, with the increase in internet connectivity and increased use of mobile phones, it is possible to address through digital tools. While, supply chain management, traceability, branding and promotion are some of the ways that digital tools are assisting farmers in solving marketing problems. The blockchain technology can revolutionize the agriculture industry by enabling traceability, improved food safety, streamlined financial transactions, and the collection as well as sharing of agricultural data (Krithika L.B., 2022). Digital technologies like automated processing equipment and sensors can be used in post-harvest management to reduce the wastage of produce due to higher relative humidity in the area (Table 6).

Table 6. Digital tools for Market Linkages

Name	**Type**	**Features**
SeedCast	Web-based platform & Mobile App	Provides seed demand for different varieties of rice and thereby assists in producing the desired seeds in sufficient quantities.
IIRR rice seed portal	Web-based platform	Provide information about the availability of seeds of each variety.
Kisan Bandi	Web-based platform & Mobile App	e-marketplace for online marketing of farm produce
Krushi Yantradhaare	Mobile App	Assist small and marginal farmers to hire machinery and also ensures transparency in bookings and reaching the specific farm for which booking has been done
e-crop/Karshak app	Web-based platform	Provision for entering crop type, acreage and thereby estimation of market-arrivals
Kalgudi	Web-based platform	Interactive platform & mobile application which provides input-output market linkages, advisories, community interaction, etc.
Agrostar Agri Doctor App	Mobile App	There is provision for online shopping of agricultural inputs in the mobile application and also provides advisory services
DeHaat	Mobile App	Provides multiple services, including frequent crop reminders, voice calls in regional languages, crop advisories, weather reports, local mandi rates, etc.
Bighaat	Web-based platform & Mobile App	Enables shopping for a wide range of Agri products (seeds, pesticides, fertilizers, and equipments) and also ensures connection among farmer communities
Ninjacart	Web-based platform & Mobile App	It is India's largest Fresh Produce Supply Chain Company that obtains fresh produce from farmers and sell to businesses, across the country
e-NAM	Web-based platform	An online trading platform for agricultural commodities in India that ensures better price discovery and provides facilities for smooth e-marketing of produce
REACH - ADAMA India	Mobile App	Provides mandi prices and timely weather alerts in 7 languages
Vyavasaya Yanthralu	Mobile App	Online marketing app for agricultural machinery in the Telugu language
Agrim	Mobile App	An application that connects manufacturers directly with retailers for agri-inputs

Name	Type	Features
Krishify	Web-based platform	It is an inclusive digital platform that brings together farmers from across the country and other stakeholders such as sellers, traders, agriculture experts, distributors, veterinary experts, transportation service providers and farm input manufacturers. It aims to connect these stakeholders on a single platform to enable problem-solving, in terms of information and transactional needs of farmers.

6. Financial Services

The financial status of the farmer is more worsened because of all the challenges posed by coastal environment. Digital tools are enablers for penetration of financial services to farmers in rural areas. Digital technologies like block chain technology can improve efficiency and reduce the costs of agricultural financing. Digital tools play a significant role in farm management and financial services by enabling record keeping, database management, increasing accessibility of financial services, etc. Some of the digital tools which provide services in coastal ecosystems are presented in Table 7.

Table 7. Digital tools for Financial Services

Name	Type	Features
Rythu Nestham	Mobile App	Provides crop insurance information
Rythu Bandhu, Telangana State	Mobile App & Web-based platform	Enhances agriculture productivity and income of the farmers, besides breaking the vicious cycle of rural indebtedness.
Rythu Bhima	Web-based platform	Maintains farmer-wise land database & provides crop insurance information
Khetibuddy	Web-based platform	Premier enterprise farm management software helps in collecting, measuring, advising, and trying to improve your farming habits.
Agworld	Web-based platform	Accounting, and inventory management services.
PM KISAN	Web-based platform	Provides updates and information on the PM KISAN scheme.

Conclusions

Digital tools have the potential to play a pivotal role in fostering sustainability in coastal agriculture ecosystems. Monitoring and analyzing crop health, predicting and mitigating the effects of natural disasters, and aiding in the management and conservation of natural resources are some of the areas benefitting farmers in coastal regions. Agriculture can become profitable by increasing efficiency of farming through use of digital tools based on the requirements and needs of the local farmer. Overall, adopting and implementing digital tools in coastal agriculture has the potential to greatly enhance our knowledge of these ecosystems and our capacity to safeguard them for future generations. It is recommended that capacity building activities in digital tools to local communities can transform and sustain coastal ecosystems.

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Utilisation of Palmyrah (*Borassus flabellifer* L.) Palm for Sustainable Development in Coastal Areas

P.C. Vengaiah[1], S. Kaleemullah[2], M. Madhava[2], A.D. Srikanth Tangirala[2]

[1] Dr.Y.S.R. Horticultural University, Andhra Pradesh, India
[2] Acharya N.G. Ranga Agricultural University, Andhra Pradesh, India

Sugar yielding palms are known to mankind for their economic potentialities. Palm belt in the world roughly extends from 44 degrees South latitude to 45 degrees North latitude and widely encompasses the tropical countries like Congo, Sri Lanka, India, Bangladesh, Indonesia and Malaysia. The palm, botanically known as palmate, has been termed the princess of the vegetable kingdom. The family of palms contains some 1,100 species, widely diffused over the globe, but they are common in the tropical countries.

In India, there are four varieties of sugar-yielding Palms Date (*Phoenix Sylvestris*), Coconut (*Cocos Nucifera*), Palmyrah *(Borassus Flabellifer* L.*)* and Sago (*Caryota Urens*). It is impossible to overestimate the utility of palms. They give food, shelter, timber, fuel, building materials, sticks, fibre, paper starch, sugar, oil wax, wine, tannin, dyeing materials, resin and a host of minor products. Palm trees thrive on non-agricultural lands on the banks of streams, rivers and canals, on undulating hill slopes and sandy lands which are normally unfit for cultivation. They do not require much attention.

Palmyrah palm - *Borassus flabellifer* L., the Asian variety is a genus of six species of fan palms, native to tropical regions. It is an important multipurpose tree of great utility, grows extensively in North and Eastern part of Sri Lanka, southern part of India and in most of the tropical countries. The palmyrah palm is described as the single most useful plant in the Northern region of Sri Lanka and engages human labour in the industries around it irrespective of gender or age. It is easily cultivated and also found to grow wild. Cultivation requires little labour in planting the nuts and protecting them from cattle till they grow above reach. The growth of the tree is very slow and it takes from 15 to 30 years to bear. The palmyrah palm is a large tree growing up to 30 m high and the trunk may have a circumference of over 1.5 meters at the base. The trunk is black in colour and looks like cylinders. It is also corrugated by the semi circular scars of fallen leaves. The tree can be easily recognised by its gigantic fan shaped leaves. There may be 25-40 fresh leaves and they are leathery, gray green, fan-shaped, 1-3 meters wide and folded along the midrib and they spring at the top in a clump.

They are usually very tough and have thick stalks. There are two kinds of the palmyrah - the male and the female. The male and female flowers are held by two different trees, never in one tree. Both male and female trees produce spikes of flowers but only the female plant bears fruits. However, both trees are used to tap toddy. The flowers are small and appear in densely clustered spikes, developing into large, brown, roundish fruits. The male flowers are smaller than the female flowers. Palmyrah is a very important palm and playing an important role in the day-to-day life of poor and landless farmers. Palmyrah palm adorns the dry landscape of the semi arid tropics of Tamil Nadu, Andhra Pradesh, Orissa, West Bengal, Karnataka and Maharastra. Due to its multifarious uses, the palm is equated to the “Kalpa Vriksha” in the mythology. Like the coconut, palmyrah is regarded as a total palm as each and every part of the palm right from fruit to root is having many fold economic uses. Though growing of this important palm has an immense potential, no determined effort has been made to bring the palm under cultivation. Palmyrah referred as tree of life with nearly 800 uses including food, beverage, fibre, fodder, medicinal and timber.

Among the various edible uses of the palm, the sweet sap tapped from the inflorescence for making palm sugar is of prime importance. The endosperm of the young fruit, like tender coconut, is a delicacy in summer. The petiole fiber and leaf blade are used to make products such as brushes and handicrafts. The tree serves as a source of raw material for several cottage industries. Further palmyrah palm act as shields or windbreakers in coastal areas to the wind which blows with very high speed. They break the force of these winds which can otherwise cause great damage like soil erosion.

Palmyrah based products

Edible	-	Neera, Palm Jaggery, Palm Candy, Palm Sugar, Fruits Jam, Syrup, Chocolates, Toffees, Confectionery items are made by Palm Sugar.
Non-Edible	-	Palm Fibre Brush, Palm Leaf Fancy Articles, Naar Articles, Palm Leaf Visiting Cards.

Edible products

Neera

Neera is the top most economic produce of palmyrah. It is good source of minerals like calcium, phosphorus and iron. Vitamin - A, citric acid, Niacin, Thiamin and Riboflavin are present in neera. Neera acts as laxative and diuretic. Neera the delicious drink extracted from the sap of the palm is fast becoming popular in rural and urban areas of India. Refreshing as it is, the drink has agreeable flavour, high nutritive value and medicinal properties. It is whole some, cool and good for improvement of general health, especially as a supplement to those who have iron and vitamin deficiency. The popularity of system cool and improves appetite and digestion. It can be consumed in fairly large quantity without causing any damage to the system. As a good tonic to the asthmatic, anemic and leprosy patient, Neera has acted miraculously. It has also cured digestive troubles. It can also be used for preparation Jaggery, Syrup, Rab, Palm Sugar, Palm Candy, and other Confectionery items, ice cream and various sweets.

Toddy

Toddy is formed as a result of fermentation of sugar sap by wild yeasts and bacteria, which come into contact with the sap. This is an uncontrolled natural fermentation by number of different strains of yeast and bacteria. The alcohol content in fully fermented toddy is around 5%. But fermentation of palmyrah sap using pure yeast cultures gives about 7.8% alcohol content under laboratory conditions. The major sugar present in partly fermented toddy are sucrose, glucose and fructose but these all are gradually converted to ethyl alcohol during fermentation.

Palmyrah arrack

Arrack is manufactured from toddy by pot still distillation and patent still distillation. The approximate recovery of potable alcohol from toddy is 10%.

Wine

Sterilized unfermented sap could be fermented with suitable strains of yeast to produce palmyrah wine. Sweet toddy, with a ph of 6-7, sterilized and inoculated with good wine yeast produce a very clear straw coloured wine. The alcohol strength increases by adding extra sugar to the sap. The wine prepared in this manner is a pleasant drink without characteristic toddy flavour and sour taste of the acids present in toddy.

Palm jaggery

It is also called as palm gur. Jaggery is made by boiling neera at 110°C. Neera gets transformed in to viscous fluid which is poured in to shells and allowed to harden. About 8 liters of neera is required to get 1 kg of jaggery. Jaggery contains good nutritive and medicinal values. It has an intense, earthy taste or reminiscent of chocolates in its taste. The palm jaggery obtained after processing is darker and richer in colour. Due to its cooling effects over human body, it is of high value. It does not have the bone meal content which is used for whitening processed sugar. The price of the palm jaggery is double that of sugar. Jaggery is a solid mixture of reducing and non reducing sugars prepared by concentration of palmyra sap, except for small changes undergone during its manufacturing. It contains all constitutes of neera and is equally nutritious. The proximate composition of jaggery is moisture (8.97%), ash (3.25%), reducing sugar (3.41%), total sugars (73.78%), Protein (1.41%) and organic matter (11.1%). Palmyrah jaggery which has adequate amounts of Ca, low sodium and high potassium is prescribed for dispensing in conditions like hypertension and oedema due to heart and liver diseases. It is recommended for the treatment of diseases with marked loss of potassium as the case of diabetic acidosis, post operate convalescence and as a general diuretic. The iron content varies from 5- 10 mg/100 g palm gur. This can profitably be used to cure anaemia. Jaggery contains very little amount of nitrogen. With regard to carbohydrates, it contains higher amount of non reducing sugars than reducing sugars. The higher amounts of sucrose and glucose justify the recommended use of palm gur as good energy source for convalescents, since in that stage one requires readily available energy providing food. It contains vitamins like B_{12} and C.

Palm sugar

With sucrose content 12%w/w and purity of about 80%, the sap forms a suitable material for production of sugar. Palm sugar can be substituted to cane sugar in all preparations. It has high dietetic values and healing properties against disease of the eye. It is also recommended for infants and people of old age. It contains protein (0.24%), fat (90.37%), minerals (0.5%), carbohydrate (98.89%), calcium (0.08%), phosphorus (0.06%), iron (30 mg/100 g), nicotinic acid (94.02 mg/100 g) and riboflavin (92.29 mg/100 g) with calorific value of 398 k calories/100 g.

Palm candy

Neera free from debris should be boiled in an alloy vessel adding small quantity of superphospate. After uniform boiling, the liquid is allowed to cool. After removal of sediments, it is heated to 110°C for 2 hours until it reaches honey like consistency. The fluid is then allowed to cool and poured in to crystallizer. Sugar crystals start forming after 45-60 days.

Palm cola

Palm cola is an aerated soft drink containing 11% sugar. Its other ingredients are cola concentrate, citric acid and food colour. The palm sugar is treated with milk and its impurities are removed while boiling to temperature of 110°C-115°C. The boiling is stopped at 53 °Brix and the mixture is filtered through a filter press. Cola essence is added to mixture after cooling at the rate of 250 ml/1000 botles of palm cola. Bottles of 200 ml, previously sterilized are filled with the mixture at the rate of one fluid/bottle. This is carbonated with carbon dioxide and sterilized water. About 1 kg of purified palm sugar is sufficient to produce 300 bottles of palm cola.

Confectionary

Presently made of its sugar is chocolates and toffee. A mixture of glucose and palm sugar is boiled to a temperature of 120°C. The heated mixture is put into trays and mixed with powdered citric acid. A mixture of colour and essence is then added. The entire mixture is mixed well and cut into slabs, allowed to cool and packed. Thirst due to excess of heat, urine trouble due to heat, over heat due to small-pox and remedy for cough and cold will be cured with palm candy.

Palm honey

Neera is heated for 2 hours to obtain the honey like consistency. The syrup then is transferred to mud pots. Ripe, dry and shelled tamarind fruits devoid of seeds are added in to syrup. About 1 kg of fruit is required for adding to10 liters of syrup. The pot is closed tightly with cloth and vessels are kept in a shock proof, cool and dry place for 130–180 days. Sugar crystalizes on the sutures of tamarind and the fruits become delicious.

Palmyrah fruit

Fruits are used in both young and ripened stage for directly and for various value added products.

Young/tender fruit (Nungu)

When the fruit is very young, and the top of the fruit is cut off there will be three sockets inside and these contain the kernel which is soft as jelly, and translucent like ice, and is accompanied by a watery sweetish liquid. The British named this as “ice apple” as it resembled ice. This is one of nature's delicious ironies. Nungu cools many dried throats on a hot summer day, tastes best when it comes from arid fields. In South India, during summer the road side vendor pile up these young fruits, cut the shell and pop out the heart shaped icy Nungu for the customers. It is nutritious when eaten in its natural form. This fruit is loaded with minerals and absolutely no fat and protein. The coconut-like fruits are three-sided when young, becoming rounded or more or less oval, 12-15 cm wide and capped at the base with overlapping sepals. Jelly like endosperm of young fruit of 60 – 70 days old is called nungu which is a summer delicacy. It is very nutritive. Young fruits are freshly marketed in big cities, sometimes far away from the place of origin. The fruit bunches are brought from the villages to the markets in the cities and then redistributed to, small-scale fruit vendors. The vendors cut open each fruit and remove the three young kernels along with the white skin (endocarp). When serving, the white skin is neatly removed and the kernels appear glassy white. The kernels are usually packed in polythene bags (about 10 in each bag) and kept in ice to keep it fresh. The young fruit is soft fleshy contains watery sweet kernel and consumed as fresh. The tender kernel contains sucrose (0.38%), fructose (1.46%) and glucose (93.21%) as free sugars. The value added products from young fruit is Nungu candy, jam, jelly, squash, concentrate, RTS beverage and Nungu peda,

Ripened Fruit

Each female palm may bear 10-15 bunches of about 150-250 fruits per year. This fruit is loaded with minerals and absolutely no fat and protein. Palmyrah pulp is mixed with other fruits for making jam, cordial, cream etc. Since its pulp is bitter in taste, it is better to prepare mixed fruit jam rather than palmyah jam separately. To prepare cordials, citric acid is added to its diluted pulp and boiled. Well boiled cordial is bottled in white or amber colured bottles after adding approved food preservative. Sometimes a stabilizer is also added to prevent separation of layers after bottling. Pulp from fruit was used in preparation of household foods mixing with idli ravva, deep fried items and leather. Fruit gives sweet aroma with fleshy mesocarp. The outer covering is smooth, thin, leathery, and brown, turning nearly black after harvest. Inside is a juicy mass of long, tough, coarse, white fibres coated with yellow or orange pulp. Within each mature seed is a solid white kernel which resembles coconut meat but is much harder. The mature fruit is usually tossed over low burning fire or embers to cook them mildly and the skin is peeled off to expose the juicy fruit. This is squeezed and the pulp removed. The pulp in itself is sweet and creamy and is delicious to eat. The pulp is usually sucked directly from the fibres of the fruit. The fresh pulp is reportedly rich in vitamins A and C. Palmyrah fruit pulp could be commercially utilized to produce food items and animal feed. The whole fruit contains about 40% of undiluted pulp which is dark yellow in colour with its characteristic flavor and bitterness. The pulp is extracted manually with water. A mechanical extractor for obtaining fruit pulp from palmyrah palm was designed with squre baldes on rods fitted at an angle to a vertical shaft driven by 0.75 hp motor, with speed adjustable via a gear box.

Receipe from fruit: Squash, Ready to serve juice, Leather, health mix, snack items etc.

Tuber (Apocolon): Mature tuber is brittle and breaks off easily which is rich source of carbohydrates. Optimum time for harvesting of tuber is 135 days after sowing. Farmers produces tuber in the field by collecting nuts from palmyrah fields. Farmers sells tuber by roasting in open fire with inverted iron tin and makes bundle of 5-6 tubers and sell for Rs. 10/-. The family of two members along with two farm labour, earns daily Rs.2000-2500/- during the season.

Receipe from tuber: Dehydrated palmyrah tuber, Palmyrah tuber flour and rava, Palmyrah tuber laddu, palmyrah – soya laddu, palmyrah tuber kesari, palmyrah tuber payasam, palmyrah tuber idli, palmyrah tuber uppuma, Palmyrah tuber porridge, Palmyrah tuber pakora.

Thavan (spongy haustorium): Thavan is formed during germination of seed nut is spongy, sweet and delicacy.

Non edible products

Leaves: Matured leaves are cured and are primarily used for thatching houses and for making mats. In addition they are also used for making of several value added utility articles which are in high demand. Leaves have been used for writing scripts since time immemorial. Senesced leaves are utilized as fuel. The leaves are used for thatching roofs, screening as fence, as mats, baskets, fans, hats, umbrellas, buckets, sandals and as writing material.

Petiole: Tough and long fiber extracted from Petiole (vadapa) is used for making of ropes used in building of houses and boats. Apart from this it is also used in making several kinds of utility and fancy articles which are in good demand. Dried up leaf petioles are also in use for making of trellies for use as fence and it further serves as a fire wood.

Matured fruit: Mesocarp of the matured fruit also yields small quantities of fiber. Fleshy pulp is removed from the fruit and it is dried to expose the fiber adhering to the stone. This fiber is used for making of fancy items and toys.

Stem: Palmyra trunks are used either as live poles in construction of thatch sheds or as a timber in replacement of wooden poles. The trunk of the tree is hallowed, and is directly used as boat (Dhone) for travel and fishing in many parts of the tropics. Trunk of grown up palm is cut and used as rafters.

Leaf base fibre: this fibre is most economical, each palm gives 2 kg fibre per year and one person can collect manually 10 kgs per day and sell @ 20/- per kg of wet and earn Rs. 200-300/- per day. In Andhra Pradesh commercial units with machinery are operating and earning one lakh per month.

Scope for palmyrah based industry in coastal areas

1. Neera Catering Unit
2. Palm Jaggery Making unit
3. Palm Candy Making unit
4. Palm Sugar Making Unit
5. Confectionery and Indigenous Sweet Making Unit
6. Palm Fibre Processing and Marketing Unit
7. Palm Fibre Processing and Marketing Unit (Export Oriented)
8. Table Top Palm Fibre Brush Making Unit
9. Palm Leaf Fancy Articles/ Visiting Cards Making Unit,
10. Other bye products like Palmyrah Vinegar, Naar articles.

Name of the training centres under KVIC

1. Dy. Director –Principal, Gajanan Naik Multi Disciplinary Training Centre, KVIC, At. Post. Dahanu Dist. Thane – 401 601 (Phone No. 02528-222241)
2. Dy. Director-Principal, Central Palmgur & Palm Products Institute, KVIC, Kumarappapuram, M.M.C. Post, Chennai –600051. (Phone no.- 044-25555402)
3. Dr. B.R. Ambedkar Institute of Rural Technology and Management, KVIC, Post Trimbak Vidhya Mandir, Nasik - 422 213.

Other institutes working on palmyrah based products

1. ICAR- AICRP Palms: Dr. YSRHU-HRS Pandirimamidi, ASR District, Andhra Pradesh.
2. A.P. State Palmgur Coop. Federation, P.O. Nidadavole, Dist. West Godavari, Andhra Pradesh.
3. Gujarat State Palmgur Coop. Federation Ltd., C/o. Neera & Tadgud Utpadak Sahakari Mandali, 3/4265 Bonde lawad, Surat, Gujarat
4. Orissa State Palmgur Coop. Federation Ltd., At Udyogpuri, Post Khandagiri, Gundamunda, Chowk, Bhubaneswar-30. Orissa
5. The Trivandrum Dist. Palm Product Dev. Coop. Fedn. Ltd., Parassala, P.O. 695 502, Kerala State.

6. Tamilnadu State Palmgur Federation Ltd., 160 Neera Mansion, Gengu Reddy Road, Egmore, Chennai-600 008.

7. West Bengal State Palmgur Coop. Federation, 4, Bepin Paul Road, Calcutta - 26.

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Palmyrah neera

Palmyrah jaggery

Palmyrah Neera

Palmyrah candy

Palmyrah syrup or liquid jaggery

Palmyrah jaggery powder

Fig. 1. Palmyrah neera and neera based products

Palmyrah tuber

Palmyrah tuber flour

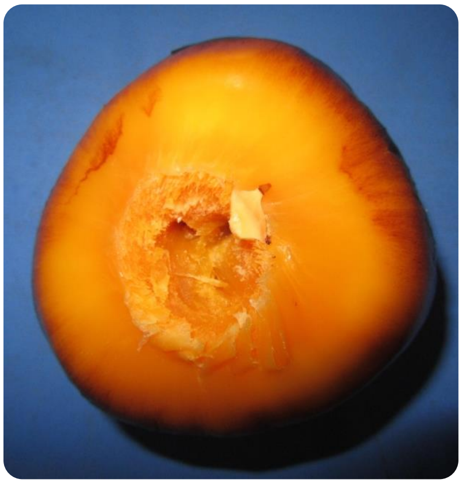
Palmyrha tuber cake

Tuber cookies

Palmyrah tuber upma

Palmyrah tuber noodles

Fig. 2. Palmyrah tuber based products



Palmyrah fruit

Fruit beverage

Palmyrah fruit lether

Palmyrah fruit flour

Fruit pulp based snack

Fruit based idli

Fig. 3. Palmyrah fruit products

Livestock Farming Systems in Coastal Areas of Andhra Pradesh

Y. Ravindra Reddy, G.V. Bhaskar Reddy and Venkata Naidu

Associate Dean, College of Dairy technology, Sri Venkateswara Veterinary University, Tirupathi-517 502
Corresponding author: yeddularavi88@gmail.com

Integrated Farming system is an innovative method of promoting the sustainable use of available natural resources incorporating livestock activities with traditional agricultural practices in a holistic manner suitable to local conditions. It is method of more efficient and effective natural resource management allowing nutrient recycling and improved diversification.

Concept of Integrated Farming System

The integrated farming system involves the integration of Agro-forestry, Horticulture, Dairy, Sheep and Goat rearing, Fishery, Poultry, Piggery, Biogas, Mushroom, Sericulture and by product utilization of crops with a main goal of increasing the income and standard of living of small and marginal farmers (Allen *et al*., 2007). The integrated system has advantage of allowing diversification of risks, using labour more efficiently, recycling waste thus preventing nutrient losses, adding value of crop and crop products while providing cash for purchasing farm inputs.

Aims and Objectives

Integrated farming system aims at increased productivity, profitability, sustainability, balanced food, clean environment, recycling of resources, income round the year (Gill, 2008). An integrated crop farming system represents a key solution for enhancing livestock production, minimizing the effects of intensive farming and safeguarding the environment through efficient usage of resources.

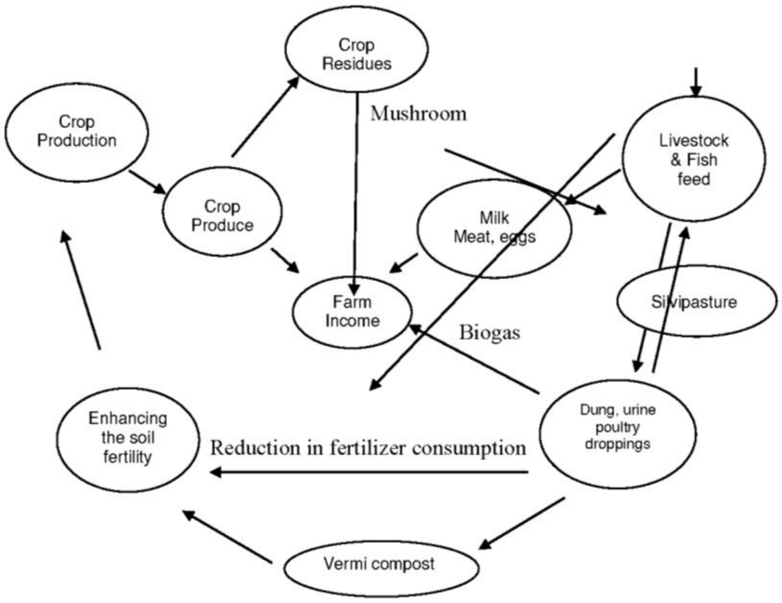
The objectives of integrated farming system should be area specific, formulate models involving main and allied enterprises for different farming situations. It should ensure optimal utilization and conservation of available resources with efficient recycling within each system included. It should raise the net return of the farm household by complementing main activity with allied enterprises. It should concentrate on developing institutional and market linkages by inclusions of new interventional technologies. It should address the nutritional insecurity of resource poor farmers vulnerability and poverty of landless labourers. The available systems should be modified and improved incorporating the scientific know how so that the system can be made viable and competitive in this era of modern agriculture (Nabhachandra Singh, 2008).

The present status and future prospects of the existing farming systems can be classified as

1. **Concept of farming system with dairy as a component**.
2. **Identification of economical and profitable integrated farming system**.
3. **Eco - efficient approaches for integration of crop and animal production systems**

1. Concept of farming system with dairy as a component

Under these circumstances, the only alternative is integrated livestock farming which will result in efficient utilization of scarce resources and providing gainful employment. Integrated farming systems are common throughout the world. They involve several sub-sectors like crops, animals, fish, sericulture, agro forestry, biogas, mushroom cultivation, horticulture, vermi culture, silvipasture etc., which are used in a mutually reinforcing manner. The interactions of these components are synergistic, and result in greater total effect than the sum of their individual effects. More specifically, the benefits often result in ecological and economic sustainability.



The rationale for the type, extent and intensity of integrated farming systems is influenced to a very large extent by environmental dictates, notably, rainfall, temperature and elevation, availability of local resources, and market opportunities. Diversification is central to such efforts, and integrated farming systems also have other distinct advantages as follows:

- diversification in the use of production resources
- reduction in, and spread of, socio-economic risks
- involvement of a preponderance of small farms and small farmers
- use of large populations of ruminants (buffalo, cattle, goats and sheep)
- integration of crops (annual and perennial) and animals
- use of animals and crops play multipurpose role
- low input use and traditional systems
- involvement of the three main agro-ecosystems (highlands, semi-arid and arid tropics, and sub humid/humid tropics).

Types of integrated systems

Broad categories of integrated farming systems are:

i. Crop-Livestock-forestry farming system

ii. Crop-Fish-poultry farming system

iii. Crop-Livestock-poultry-fishery farming system

iv. Crop- Agri-Silvipasture-livestock farming system

Economic benefits of integrated farming systems

Integrated farming enables more efficient utilization of land, capital, inputs and labour resources of the farmer. Hence, returns in integrated farming were in general more compared to arable farming or livestock alone farms. Further, profitability of the integrated farming varies depending upon the local factors like demand and supply of livestock products like milk. Studies conducted over a period of time in different places of India, have indicated that integrated farming with small to medium herds to be profitable in rural areas, whereas large herds were found to be more profitable in peri and semi urban areas.

Studies conducted in Gujarat, indicated that about 75 per cent of rural households kept cattle in the face of under employment and milch cattle contributed 32 and 20 per cent respectively of farm income. Whereas integrated farming with other species like goats along with cows & buffaloes contributed between 54-68.9 per cent of the total farm income.

Many agricultural practices such as agroforestry systems and integrated crop-livestock systems may play a significant role in reducing the emission and mitigating the atmospheric accumulation of greenhouse gases (GHG). These systems could help smallholder farmers adapt to climate change while contributing to restoration of degraded lands.

The concept of eco-efficiency has often been considered a key element in the development of sustainable farming systems. Eco-efficiency is related to both 'ecology' and 'economy' and is concerned with the efficient and sustainable use of resources in farm production and land management. Eco-efficiency will be increased when a given level of production is achieved using less resources, with less losses to the environment and without sacrifice to the productive potential of the land or economic performance. The efficient use of plant nutrients, pesticides and energy and the minimization of greenhouse gas emissions are all key concerns that affect eco-efficiency.

Eco-efficient agricultural production uses resources more efficiently to produce more food, enables family farms to be more competitive, and delivers sustainable increases in productivity, while avoiding natural resource degradation and negative externalities. Integration of crops and livestock was a common approach to agricultural production throughout the world. Greater integration of crop and livestock systems may impart major benefits to the environment and to development of sustainable agricultural production systems. The agricultural revolution over the next 40 yr has to be the eco-efficiency revolution, with which scarce resources of land, water, nutrients, and energy are used.

Integration of crop animal farming systems

Population growth, urbanization and income growth in developing countries are fuelling a substantial global increase in the demand for food of animal origin, while also aggravating the competition between crops and livestock (increasing cropping areas and reducing rangelands). The livestock revolution is stretching the capacity of existing production, but it is also exacerbating environmental problems. Therefore, while it is necessary to satisfy consumer demand, improve nutrition and direct income growth opportunities to those who need them most, it is also necessary to alleviate environmental stress. Conventional agriculture is known to cause soil and pasture degradation because it involves intensive tillage, in particular if practiced in areas of marginal productivity. Technologies and management schemes that can enhance productivity need to be developed. At the same time, ways need to be found to preserve the natural resource base. Within this framework, an integrated crop-livestock farming system represents a key solution for enhancing livestock production and safeguarding the environment through prudent and efficient resource use. The increasing pressure on land and the growing demand for livestock products makes it more and more important to ensure the effective use of feed resources, including crop residues.

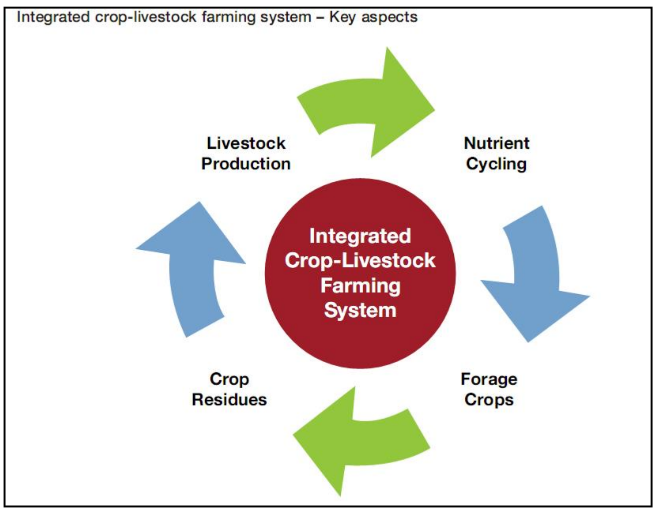
An integrated farming system consists of a range of resource-saving practices that aim to achieve acceptable profits and high and sustained production levels, while minimizing the negative effects of intensive farming and preserving the environment. Based on the principle of enhancing natural biological processes above and below the ground, the integrated system represents a winning combination that

(a) reduces erosion

(b) increases crop yields, soil biological activity and nutrient recycling

(c) intensifies land use, improving profits

(d) can therefore help reduce poverty and malnutrition and strengthen environmental sustainability.



3. Eco -efficient approaches for integration of crop and animal production systems

In an integrated system, livestock and crops are produced within a coordinated framework. The waste products of one component serve as a resource for the other. The result of this cyclical combination is the mixed farming system, which exists in many forms and represents the largest category of livestock systems in the world in terms of animal numbers, productivity and the number of people it services. Animals play key and multiple roles in the functioning of the farm, and not only because they provide livestock products (meat, milk, eggs, wool, hides) or can be converted into prompt cash in times of need. Animals transform plant energy into useful work: animal power is used for ploughing, transport and in activities such as milling, logging, road construction, marketing, and water lifting for irrigation. Animals also provide manure and other types of animal waste. Excreta has two crucial roles in the overall sustainability of the system:

(a) ***Improving nutrient cycling:*** Excreta contains several nutrients (including nitrogen, phosphorus and potassium and organic matter, which are important for maintaining soil structure and fertility. Through its use, production is increased while the risk of soil degradation is reduced.

(b) ***Providing energy:*** Excreta is the basis for the production of biogas and energy for household use (e.g. cooking, lighting) or for rural industries (e.g. powering mills and water pumps). Fuel in the form of biogas or dung cakes can replace charcoal and wood.

Crop residues represent the other pillar on which the equilibrium of this system rests. They are fibrous by-products that result from the cultivation of cereals, pulses, oil plants, roots and tubers. They are a valuable, low-cost feed resource for animal production, and are consequently the major source of nutrients for livestock in developing countries. The integrated crop livestock system has many advantages which include

- It helps improve and conserve the productive capacities of soils, with physical, chemical and biological soil recuperation. Animals play an important role in harvesting and relocating nutrients, significantly improving soil fertility and crop yields.
- It is quick, efficient and economically viable because grain crops can be produced in four to six months, and pasture formation after cropping is rapid and inexpensive.
- It helps increase profits by reducing production costs. Poor farmers can use fertilizer from livestock operations, especially when rising petroleum prices make chemical fertilizers unaffordable.
- It results in greater soil water storage capacity, mainly because of biological aeration and the increase in the level of organic matter.
- It provides diversified income sources, guaranteeing a buffer against trade, price and climate fluctuations.

In integrated systems the exchange of resources such as dung, draught and crop residues take place in deferent degrees based on the availability of land, labour and capital respectively (Fig. 2).

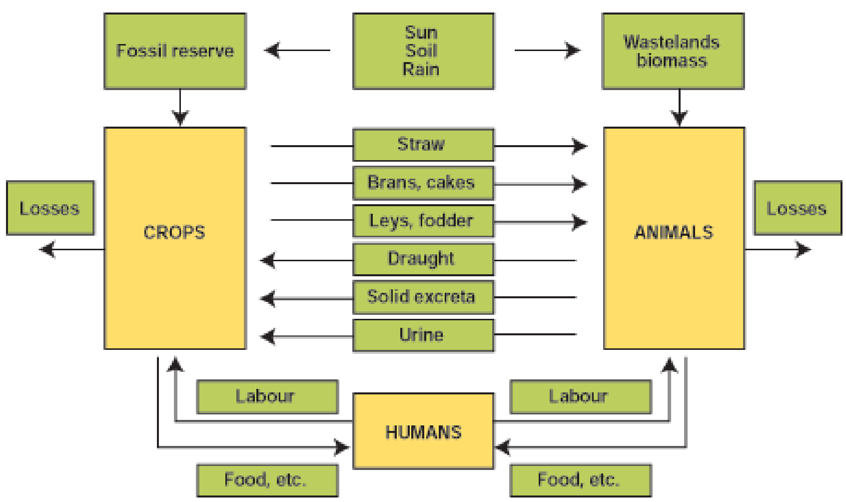


Fig. 2. An outline of different resource flows in mixed crop-livestock systems

Most positive contributions of livestock to the environment are related to their role in integrated sustainable farming systems. In Asia, through centuries of experience, the integration of livestock, fish and crops has proved to be a sustainable system. In China, for example, the integration of fishpond production with duck, goose, chicken, sheep, cattle or pig raising increased fish production by two to 3.9 times. Also recognized were the ecological and economic benefits of fish utilizing animal wastes, a manageable system for small-scale farming. Environmentally sound integration is ensured in these systems: livestock droppings and feed wastes can be poured directly into the pond, where they constitute feed for fish and zooplankton; livestock manure can also be used to fertilize grass, which also constitutes feed for fish; vegetables can be irrigated from the fish ponds, and their residues and by-products can be used for feeding livestock.

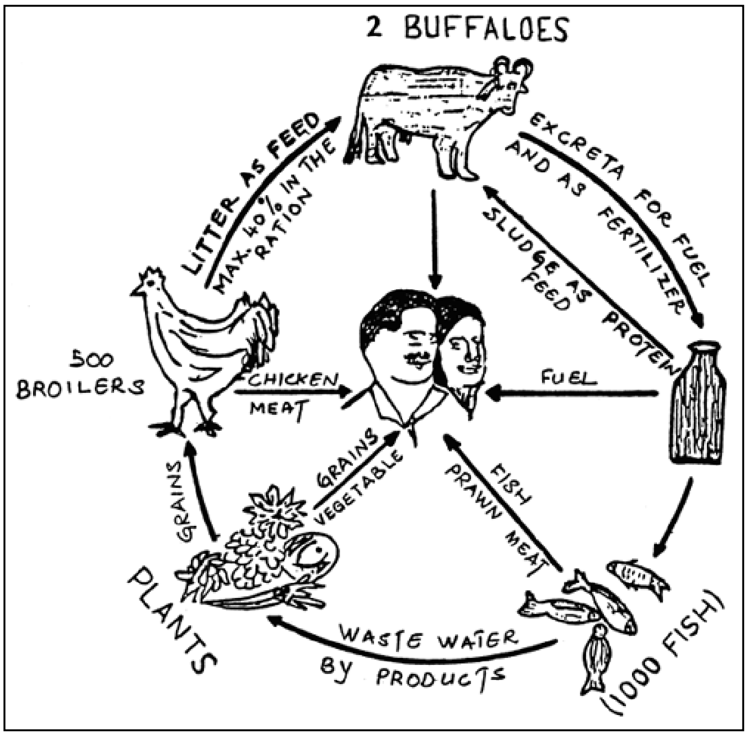


Fig. 3. Integrated recycling model farm concept

The introduction of sheep grazing on legume forage/fuelwood fallows within traditional farming systems (cassava shifting cultivation) has been shown to greatly benefit the environment. In this way, degraded lands can be rehabilitated for crop production and further use of less fertile lands can be reduced. Maximizing both integration and recycling ensures the sustainability of animal production/agricultural systems. Such a system is now operational at the small-farmer level in Colombia and supports high levels of production (more than 3 000 kg of meat per hectare per year). It includes pig, sheep, duck and earthworm raising (in partial or total confinement), food crops, environmentally protective perennial crops such as sugar cane, nitrogen-fixing trees (***Gliricidia septum*** and ***Erythrina fusca***) or other multipurpose trees and water plants (***Azolla filiculoides*****).** Feed (sugar-cane juice for pigs and ducks, bagasse and tops for ruminants, fodder from trees and aquatic plants), energy (biogas and tree branches) and fertilizers (effluent from biodigester and humus made by earthworms) are all produced on the farm.

Approaches to increase eco-efficiency

Increased ability to predict the availability of nutrients from soil and manures and better knowledge of threshold levels for weeds, pests and diseases provide the basis for precision farming with substantial reductions in external inputs and reduced environmental losses.

Reduction in rumen methanogenesis

A major challenge in eco-efficient crop animal production is that the greater output and efficiency has to be achieved without further GHG emissions while maintaining or restoring agroecosystems. Considerable evidence of climate change associated with emissions of greenhouse gases (GHG). mainly carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) in the atmosphere has resulted in international efforts to reduce GHG emissions. The annual global methane production from livestock is about 80 Tg from enteric fermentation and India's contribution is about 11 Tg per year, which corresponds to 14 per cent of globaval influx of methane. Methane production by Indian cattle, buffalo, sheep and goat was 76.7, 97.0, 11.6 and 10.1 g/head/d, respectively. The nature and rate of fermentation of carbohydrates influence the proportion of individual VFA formed and thereby the amount of CH_4 produced in the rumen. Methane emissions from ruminant animals are reduced when they are fed some forage species

Land use to maintain soil fertility

Soil organic matter content decreases with continued cultivation and cropping with arable crops, but increases under grass. It was found that changing land use from more or less continuous cereals to pasture increased soil organic carbon from 1.2 to 1.8% in 10 years, with soil N increasing from 0.13 to 0.17%. The annual increments in soil C and N were 1000 and 75 $\mathrm{kg\,ha^{-1}}$, respectively. With grass, not only does organic matter content increase, but there is also an improvement in structure, as indicated by an increase in the proportion of water-stable aggregates.

The replacement of native perennial vegetation with annual crops (wheat and subterranean clover) results in a dramatic increase in deep drainage and aquifer recharge. Consequently, highly saline water may lead to salt accumulation in the rooting zone and reduce crop growth or cause crop failure. The inclusion of deep-rooted perennial species, such as lucerne, in a rotation will extract water to depth, reduce aquifer recharge and prevent increase in salinization. A similar approach using deep-rooted species is relevant to sustaining productivity of large areas of the world.

Improving carbon sequestration in soil

By using the concept of building an arable layer through improved carbon sequestration and combining this soil management technology with acid soil adapted cultivars of both forages and crops in integrated crop-livestock systems (agropastoral systems), farmers have the tools and technologies to transform the low fertility acid soils to increase agricultural productivity and mitigate climate change. In addition, an effective natural inhibitor of nitrification was discovered in the root-exudates of the tropical forage grass ***Brachiaria humidicola*.** Acid soil-adapted improved forage grass options with ability to regulate nitrification in soil and to reduce emission of N2O to the atmosphere can make significant contribution to improve nitrogen use efficiency of crop-livestock systems. The integration of these carbon and nitrogen technologies can improve the economic and ecological sustainability of crop-livestock systems in low fertility acid soil regions.

Conclusions

It can be concluded that eco-efficient farming should satisfy the following five key attributes:

i. it uses resources efficiently and makes the maximum use of renewable inputs,

ii. it is neither locally polluting nor does it transfer pollution to elsewhere,

iii. it provides a predictable output,

iv. it conserves functional biodiversity in relation to strengthening ecological processes, reducing greenhouse gas emission and pollution generally and limiting soil erosion,

v. it is capable of responding rapidly to changes in the social, economic and physical environment. It is also crucial that eco-efficient farming satisfies economic criteria in relation to farm profitability.

Precision nutrient management in cropping systems

V. Chandrika, K. Poojitha and B. Himasree

Department of Agronomy, S.V. Agricultural College, Tirupati – 517 502

Nutrient management involves using crop nutrients as efficiently as possible to improve the productivity while protecting the environment. The key principle behind nutrient management is balancing soil nutrient inputs with crop requirements. When applied in proper quantities and at the right times, added nutrients help achieve optimum crop yields, but applying too little will limit yield and applying too much does not make economic sense and can harm the environment. Nutrients that are not effectively utilized by crops can potentially leach into groundwater or enter nearby surface waters and can impair water quality.

In recent years, the potential to mitigate climate change by improving nutrient use efficiency (NUE) in croplands has received considerable attention in the agricultural research and policy agendas. The use of chemical fertilizers, nitrogen (N) in particular, in crop production is at the center of managing both food security and environmental sustainability. Enhancing crop yields through increased use of nutrients is essential to meet current as well as future food demand. On the other hand, because fertilizer application in croplands is a major source of anthropogenic nitrous oxide (N_2O) emissions, reducing greenhouse gas (GHG) emissions through proper fertilizer management is essential to address agriculture's contribution to climate change. Moreover, excess and improper use of nutrients in crop production have large cost implications for the farmers. Therefore, improving NUE in croplands provides the opportunity to address the triple challenge of food security, farmers livelihood and environmental protection, globally.

Another major concern for precision nutrient management in coastal regions is coastal eutrophication. Coastal agriculture area remains the intricate network of streams, tributaries and rivers. Agricultural runoff from these areas is one of the main ecological problems for coastal zones around the world. The increase in nutrients has created multiple consequences on marine ecosystems, such as harmful algal blooms, zones of hypoxia or anoxia, and loss of biodiversity. Adoption of precision nutrient management in coastal area can reduce the nutrient load in the runoff and sediments there by addressing coastal eutrophication.

To address the challenges of global food security, environmental pollution, and climate change, it is imperative to develop precision nutrient management (PNM) strategies, which can sustainably increase the productivity and resilience of cropping systems, while reducing greenhouse gas emissions. PNM is a promising approach for synchronizing soil nutrient supply with crop nutrient demand both in terms of time and rate of nutrient application. In PNM inputs are applied at right time and right place and in right quantity and right method by using the field variability.

Site Specific Nutrient Management (SSNM) involves optimizing nutrient inputs considering demand (plant needs) and supply (from soils indigenous sources) of the nutrients according to their variation in time and space thereby ensuring field-specific nutrient management in a particular cropping system. Various technologies and practices such as Chlorophyll Meter, Leaf Color Chart, GreenSeeker and decision support systems for instance Nutrient Expert (NE) and Rice Crop Manager are available for helping farmers to implement SSNM and improve NUE.

The chlorophyll meter enables users to quickly and easily measure potential photosynthetic activity, which is closely linked to leaf chlorophyll content, crop N status, and leaf greenness. Similarly, LCC centric nitrogen supervision aids farmers to assess the actual time of N requirement to the crop and guarantees N saving without conceding the crop productivity. The application of LCC in irrigated situation has been reported to save 23 kg N (50 kg Urea/ha). The green seeker sensor based technology also results in saving of N to the tune of 10–20% compared to blanket state recommendations while maintaining similar crop yields.

The NE tool was developed to implement crop nutrient management specific to farmers fields with or without a soil test. Adoption of NE-based site-specific nutrient management across all rice and wheat growing areas in India would translate into additional grain production of 13.92 Mt, reduced N consumption by 1.44 Mt and reduced GHG emissions of 5.24 Mt CO_2 per year over farmers current practice. In smallholder production systems, where soil testing of each field is nearly impossible, a simple decision support tool such as NE could be helpful to promote site-specific nutrient management contributing to both food security and environmental sustainability goals. NE-based nutrient recommendation can be scaled-up through government extension systems and schemes.

An additional emerging dynamic tool for precision nutrient management is precision farming which is a holistic approach and often considered to be the sustainable option in the era of digital agriculture. The key component of precision nutrient management in precision farming is the maps showing spatial patterns in field characteristics. Obtaining information for this map is often achieved by soil sampling. This approach, however, can be cost-prohibitive for grain crops. Soil sampling strategies can be simplified by use of auxiliary data provided by satellite or aerial photo imagery. A variable rate technology (VRT) applicator equipped with geographical positioning system (GPS) and geographical information system (GIS) guides in variable application of inputs (fertilizers) according to the soil variability. The management zone strategy reduced the average N applied from 6.3% to 46.1% compared to uniform N management. The variable rate N application using management zones reduced N application from 6.3% to 46.1% and increased net returns from 11.75 to $ 39.17/ha over uniform N management.

Variable rate technology (VRT) can be a boon for developing country like India. At present the major challenge for adoption of VRT in India is small & scattered land holdings and diverse cropping pattern of farmers. Some other challenges which limit the use of VRT are high initial cost of machinery and its maintenance and running cost, lack of technical staff and poor network of providers for custom hiring purpose. However, proper strategies especially for land consolidation, custom hiring may help in application of VRT in agriculture sector. Besides this some local interventions considering the needs of small and marginal farmers can promote the use of VRT in an efficient and economic manner.

Assessing the variability by traditional methods is time consuming and laborious. Hence, now a cost-effective, real-time soil nutrient sensor that delivers a result in less than five hours has been advanced by the EU-funded NUTRI-STAT project. The device measures nitrogen, phosphorus and potassium micronutrients, as well as the electrical conductivity and pH of the soil and displays the readings on a remote LCD controller. This pioneering technology ensures efficient application of fertilizers.

Apart from the above mentioned precision technologies, few technologies like integrated nutrient management with soil application of chemical fertilizers on the basis of soil analysis, together with use of organic manures, compost and crop residues are a useful option to harvest potential crop yields. Inclusion of legumes in crop rotation and cultivating the legume crops during fallow periods may enhance the soil nutrient supply to upcoming crops. The strategy of conservation agriculture (CA) which involves reduced tillage, planned crop rotation and use of crop residue mulch also help enhance the nutrient deposition, cycling and retention within the soils with substantial improvement in soil properties. Few research studies even shows that in CA systems, fertilizer requirements are lower and nutrient use efficiencies are higher due to increase in microbial activity and efficient recycling of nutrients. Water conservation techniques such as mulching, land leveling, contouring and terracing can considerably reduce the losses of nutrients through erosion and runoff. Use of slow and control release fertilizers, and biological nitrification inhibitors can also help improve the fertilizer use efficiency and reduce the losses of nutrients.

Farmers apply fertilizers to meet the nutrient demands of the crops and the precision nutrient management technologies guides the farmers in deciding need based nutrient applications and thus improving nutrient use efficiencies while achieving high yield levels without environmental degradation.

Integration of Small Indigenous Fishes in Aquaculture Ponds for Ensuring Rural Household Nutritional Security of Sundarbans Region, West Bengal

Rinchen Nopu Bhutia*, Uttam Kumar Mandal and Dhiman Burman

ICAR- Central Soil Salinity Research Institute, RRS, Canning Town, South 24 Parganas, West Bengal-743329
Coressponding author: rinchenacademia@gmail.com

Nutritional security is a situation that prevails when every humanbeing, at all times, have physical, social, and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Attaining a nutritional security in the situation of growing population, climate change, reducing land and water resources, environmental degradation, and changing incomes and diets will require not just approaches to sustainably producing more food, but also efficient ways of producing food, reduction of food waste, and promoting improved nutritional outcomes.

In the global scenario, in 2020 around 2.37 billion people faced moderate or severe shortage of food (UNICEF, 2021) leading to nutritional insecurities. The state of undernourishment leads to the increased vulnerability to disease particularly in women and children (Caulfield *et al.*, 2004). Therefore, in developing and under developed countries there is a prerequisite to reduce the number of people suffering from undernourishment. In the developing countries, the proportion of undernourished people has been reduced by half between 1990 and 2014–2016 (UN, 2015). To combat the deficiencies of micronutrients and protein, consumption of sufficient protein rich food is necessary. The animal sourced foods are rich in proteins and micronutrients (Murphy and Allen 2003). Fish is a nutritious food that provides high level animal protein, micronutrients, essential fatty acids and vitamins. However, the affordability and availability of fishes by the poor people make it difficult for them to consume an adequate amount of animal protein (Pachón *et al*., 2007). Fishes are an important supplement to other animal protein, providing more than 50% of total animal protein intake in many developing countries (FAO, 2016). Many of the world's poorest people depend largely on fish for the supply of most of their daily animal protein (Beveridge *et al*., 2013). In addition, fish is reasonably affordable and easily available in many developing countries (Kawarazuka and Béné, 2010).

Aquaculture and its contribution to nutritional security

In present situation fish production farm capture fisheries from sea, oceans, rivers and other open water bodies are stagnant and has no further scope for increasing the production. Previously the capture fisheries contributed to about 70% of fish for human consumption but by 2016, culture fisheries i.e. aquaculture produced 53% of all fish consumed by humans (FAO, 2018). They play avital role in the global food economy by serving as a primary protein source and diet composition for about 950 million or more people worldwide. The world's average per capita fish consumption has almost doubled in less than 50 years (World Fish Center, 2002). Fish provides about 16% of animal protein for humans, which are valuable sources of minerals and essential fatty acids. They are also the primary source of omega-3 fatty acids in the human diet. Omega-3 fatty acids are critical nutrients for normal brain and eye development of infants, and prevents numerous human illness, such as cardiovascular disease, depression, and other mental illnesses (Crawford and March, 1989). In India scenario aquaculture production was about 11.23 million metric tons (Hand book of Fisheries statistics, 2020) of fish which could help in meeting the nutritional demands of its growing population. However, fish production from aquaculture and capture fisheries is growing and has an immense role nutritional security, it has fallen short in achieving its goal particularly in the rural areas. Reason could their poverty driven inability to purchase fish, lesser productive resources, institution support etc.

Status of the aquaculture and farming communities in Sundarban

The Sundarban region of West Bengal is apart of the world's largest delta formed by deposition of sediments of rivers, the Ganges and Brahmaputra. It is very unique as it has a combination of estuarine and mangrove forest ecosystems along with fresh water bodies. It is located between shallow marine ecosystem in the south and agricultural landscape in the north (Basu, 2013). The area is composed of 102 islands of which 48 are still under the coverage of forest and rest of the 54 islands have already been deforested and converted to arable lands with human settlements and other activities. The farming communities of Sundarbans have a major or primary source of livelihood from agriculture and fisheries sector. Besides these they are also involved in animal husbandry, honey collection and forestry.

In fisheries, the major aquaculture practice involves the traditional or conventional method of culture of Indian major carps along with culture of naturally recruiting small fishes. Even in the present day the aquaculture is still in its underdeveloped stages. The culture is mostly traditional and extensive with no scientific management and proper feeding regime. Beside this, the region is complex-diverse-risk prone agro-ecosystem, grappled with degraded soil, water logging, salinity problems and marginal farm holdings. Sundarban region is the most vulnerable ecosystem subjected to environmental impact like sea-level rise and climate change related extreme weather in this area has created a displacement of resident on islands for many generations and making them homeless and destitute

Major part of the population is under BPL (Below Poverty Line) with poor standards of living, 80% of the households earn their living that involve inefficient production methods in agriculture, fishing, and aquaculture in addition with multiple stressors.

In Sundarban region, the operational farm holding is very small (< 0.5 ha per household) which are further fragmented as the family expands (Mandal *et al*. 2015). The families are poverty stricken with very low investment capabilities and low land productivity. Almost every house hold possesses a single or multiple pond with very little management and productivity. Hence there is a greater necessity for improving the livelihood of the farming communities of Sundarban region, through improving the efficiency and productivity of existing ponds, which could ultimately help in enhancing the standard of living and also meeting household nutritional security.

Measure to improve the livelihood and ensure nutritional security

Aquaculture sector is one of the fastest growing sector with numerous nutritional and economic benefits, it is considered as a possible sustainable solution for food security and increased dietary nutrition in developing regions. The nutritional benefits of fish consumption have a positive link to increased food security and decreased poverty rates. Therefore, in the poverty stricken region of Sundarban West Bengal, where there exist a traditional method of Indian major carp farming with other naturally recruiting seeds with minimum inputs and management. There is an opportunity to increase the farm productivity and profitability through integration of small indigenous fishes (SIFs)in small scale aquaculture ponds in a scientific matter. SIFs will serve as a perfect candidate species as they are readily available in the nearby open water bodies and could be cultured in the household ponds along with the primary crop that is carps. The home production even in a small ponds, will serve as an important source of nutrition owing to the greater nutritive value as a source protein minerals and vitamins, the nutritive values of some important SIFs are mention in Table 1 & 2. Furthermore, small-scale aquaculture will work as a pathway to improve nutritional status and to ensure food security at the household level (Kawarazuka and Béné 2010). It will also generate a positive effects by increasing fish production, income from the sale of fish, and employment.

Table 1. Proximate composition of some important SIFs

Species	Crude Protein (%)	Crude fat (%)	Ash (%)	Moisture (%)
Ailiacoila	16.99	3.53	1.98	78.64
Amblypharyngodonmola	18.26	4.10	1.64	76.38
*Barbus*sp.	18.81	0.19	1.12	79.67
Chanda nama	18.26	1.53	3.29	65.88
Channastriatus	20.50	4.07	1.45	77.50
Channapunctatus	19.84	3.14	1.00	75.80
Clariusbatrachus	18.20	1.42	0.97	78.70
Glossogobiusgiuris	16.35	0.25	1.25	79.10
Gudusiachapra	15.23	5.41	1.55	75.07
Heteropneustisfossilis	16.43	0.40	1.30	81.03
Mystusvittatus	18.90	1.63	0.19	77.50
Mystustengra	16.81	6.28	2.83	73.67
Osteobramacotia	16.90	5.96	3.06	74.58
Puntius stigma	18.95	6.27	0.98	72.97
Puntius sarana	20.84	3.15	1.17	74.84
Puntius chola	14.08	3.05	1.19	74.43

**Mohanty *et al.* (2011)

Small indigenous fish species and its role in nutritional security

Small indigenous fish species (SIF) are defined as the fishes that attains the size up to 20-30 cm at maturity or adult stage of their life cycle. They are valuable and easily available source of protein, fatty acids and vitamins, which are not commonly available in other foods. Besides these they are also a rich source of important micro-nutrients like calcium, zinc, iron etc. (Roos *et al*. 2007) required in the human diet. In addition to its high nutritive value, many species are known for their medicinal properties such as therapeutic properties of SIFs against diseases like CHD, ADHD, asthma, night blindness etc. (Mohanty *et al*., 2011). SIFs with less than 10 cm in total length contribute significantly to calcium, iron and zinc intake as they are eaten whole, compared to large sized fish. Although small in size they constitute a major part of fish caught in the inland fisheries due to their large numbers and abundance. Their habitat includes rivers and its tributaries, swamps, wetlands, ponds and tanks, streams, beels, low lands and paddy fields. There are a huge diversity of SIFs in India and many parts of South and Southeast

Asian countries. These SIFs form a major component of food consumed by families, especially those living in the rural areas including Sundarbans and could not afford the other source of animal protein.

Puntius sp.

Mystus sp.

Amblypharyngodon mola

Ompak sp.

Channa sp.

Mix of SIFs

Fig. Pictures of small indigenous fishes of Sunbarban region

Table 2. Calcium and phosphorus content of some important SIFs (% dry matter basis)

Species	Calcium (Ca)	Phosphorus (P)	Ca/P
Ailiacoila	2.30 (0.59)	2.72 (0.70)	0.85
Amblypharyngodon mala	1.17 (0.27)	1.87 (0.44)	1.34
Chanda nama	2.01 (0.44)	2.14 (0.47)	0.94
Caricasoboma	1.94 (0.35)	2.49 (0.45)	0.78
Cirrhinusreba	2.30 (0.65)	2.78 (0.78)	0.83
Colisafasciata	2.08 (0.53)	3.21 (0.84)	0.63
Gudusiachapra	1.43 (0.33)	2.39 (0.56)	0.59
Glossogobiusgiuris	2.28 (0.45)	1.76 (0.34)	1.29
Mystusvittatus	2.09 (0.43)	2.39 (0.49)	0.87
Mystuscavasius	1.45 (0.30)	1.01 (0.21)	1.44
Nandusnandus	2.10 (0.51)	3.09 (0.76)	0.68
Ompokpabda	0.85 (0.18)	1.59 (0.22)	0.53
Puntius ticto	2.87 (0.86)	2.60 (0.78)	1.10
Puntius sophore	2.34 (0.66)	2.17 (0.62)	1.08
Xenentodoncancila	0.94 (0.21)	2.14 (0.47)	0.44

**Hossian *et al.* (1999)

Conclusions

The multidimensional problem of food in security, has arisen from numerous causes that bring about the constraints to food availability or limits access of local people to it. Fish is one of the solutions to the problem of food insecurity across the globe. As a protein-rich food, it offers a solution to the protein-deficiency conditions affecting population. It also acts as a potential income source for those engaged in fish production, processing, and marketing. Despite these advantages, rural population such as Sundarban region of West Bengal are not able to harness its potential because of the poverty linked lack of capital for investment, illiteracy, lack of knowledge of scientific fish farming etc. Thus, the low capital intensive, small indigenous fish culture with the Indian major carps will give a better remuneration as well as the help in ensuring the regional food and nutritional security.

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Subsurface Water Harvesting Techniques for Coastal Sands: Updates and Interventions for Balancing Coastal Ecosystem

M. Raghu Babu

Rtd. Professor and University Head(IDE), Soil and Water Engineering,
College of Agricultural Engineering, ANGRAU, Madakasira- 515 301,
Corresponding author: rbmovva@gmail.com

The inland aquifers are suffering from the maladies of over exploitation of ground water by way of unscrupulous pumping, the coastal aquifers encounter the danger of sea water intrusion and saline water upconing. Seasonally recharged fresh water skimming is the only alternative in coastal zones to stabilize crop production.

Along the sea coast of Andhra Pradesh, there are 8.23 lakh ha of sandy soils, of which 1.74 lakh ha have shallow water table varying from 0.3 to 3.0 m. These soils occur in narrow strip of 10 to 15 km wide and 972 km long eastern coastal strip extended from Ichapuram in Srikakulam district to Tada in Nellore district with mean rainfall of 855 mm. In the coastal sands, entire precipitation percolates into the soil because of the high permeability of coastal sands and the infiltrated rain water with lesser density form fresh water lenses which floats on the sub- surface saline ground water. Most of these coastal sandy soils do not have the provision of canal irrigation facility and have only shallow depth of good quality waters. Poor recharging rate and occurrence of clay in deeper layers are the major constraints for installation of tube wells/deep wells. In most of these coastal sands, fresh water floating at a depth of 0.5 to 3.0 m below ground level and to a thickness of 3 to 4 m over saline ground waters/clay layers. The waters cannot be extracted in high quantities by conventional tube wells as they are of water table aquifers with poor quality waters underneath. In these soils during summer months the water table falls up to 1.8 to 3.0 m below ground level. The ground water gets recharged during the monsoon season, accumulates and by middle of November the ground water rises up to 0.3 to 0.5 m bgl in most of the areas. As irrigation supplies are not possible either though canal or tube wells in most of the coastal sandy soils, the situation has forced the farmers to search for alternatives and the technique innovated traditionally is to draw water manually that collects in the dug out conical pits locally called '*Doruvus*'.

Similarly in Tamil Nadu, the coastal belt occupies about 700 km, stretching from Pulicatlake in the north to Cape Comarine in the south and 0.68 m ha is identified as coastal sandy soils. Among different types of soils, salt affected lands occupy nearly 2.04 lakh ha or 25 per cent of coastal area of Tamil Nadu. Under the situation, where ever the fresh water exists, the farmers tap them with the development of '*OothuKuzhi*' (Spring) like '*Doruvu*' system practiced in Andhra Pradesh.

The survey carried-out in the coastal belt of Guntur district, Andhra Pradesh., revealed that the groundwater being harvested through various structures such as traditional doruvu skimming pot irrigation), traditional doruvu with 1 hp pumping unit, radial skimming well with horizontal collectors using 1-5 hp pumping units, shallow tube wells with 1 hp pumping unit, two-strainer tube wells with 1-5 hp pumping unit.

Traditional '*Doruvu*'

Shallow depth fresh water being collected in dug out conical pits locally called '*doruvu's'*. The seeped water is usually collected in pitchers and then splashed on vegetables flower plants, groundnut and nurseries of paddy, vegetables tobacco and casuarina etc. The water collected from a doruvu, that occupies an area of about 200 sq.m is just sufficient for irrigating an area of 800 sq.m. Maintenance of 10-12 such *doruvu's* is a common practice for each hectare of land.

The disadvantages of traditional *doruvu's* include Wastage of productive land towards *doruvu's,* which is about 20% of the land covered under irrigation, unproductive evaporative loss of fresh water from open water surface of *doruvu's*., irrigation process involving manual splash watering requires huge application expenditure and does not permit the use of modern irrigation equipment and also more chances of proliferation of vector borne diseases like mosquito breeding in open pits.

Radial sub-surface skimming well (Improved *doruvu* technology)

To overcome the above mentioned constraints, the skimming well technology has been evolved by the All India Coordinated Research Project on Management of Salt affected Soils and Use of Saline Water in Agriculture, Bapatla Centre of Acharya N. G. Ranga Agricultural University, popularly known as 'Improved *doruvu* technology' to harvest the shallow depth fresh water in coastal aquifer without disturbing the hydro-dynamic conditions. The system consists of a collector well with lateral collector lines installed at shallow depth. The collector lines are connected to the sump on either side and imbedded for the collection of lateral flow by digging a trench. Depending on the watertable head above the collector pipes, the collectors are continuously charged with subsurface fresh waters throughout their length and water flow into the well under gravity. The recharge occurs due to precipitation, upstream canal seepage and also by recycling of irrigation water. As a result of this recharge, flow lines are sustained. The advantages of skimming well over the traditional *doruvu's* is as follow.

Over exploitation of ground water beyond the collector line depth is not possible, and it serves as control of saline ground water upconing problem (or) against sea water intrusion as commonly observed in island (*lanka)* lands. The land wastage and water evaporation is avoided and can be used for productive purposes., and this technology effectively facilitates the adoption of modern irrigation systems like drips and sprinklers and helps in improving upon the water use efficiency.

If properly planned and installed, the systems can be used to create irrigation source as well as to control watertable in the cultivable areas in the periods of submergence. With this system, sufficient water expected to be made available to *rabi* and plantation crops and effective usage of water through sprinkler and drip irrigation methods possible. The system also replaces the existing traditional '*doruvus*'.

Adaptability of skimming well technology

With built-in advantages of skimming well, the technology has become very popular with the farmers of coastal sandy belt in and around Bapatla area. With the developed technology more than 102 skimming wells covering 206 ha cultivable area being installed in 24 villages of Guntur, Prakasam, Krishna and West Godavari districts of Andhra Pradesh. Nine skimming wells with horizontal collectors were exclusively installed in Guntur district for drinking water supply with the help of NGO's and Rural drinking water scheme, Govt. of Andhra Pradesh. Similarly Tamil Nadu Agricultural University introduced the skimming technology in Myladuthrai and Nagapatnam districts by installing two skimming wells after detailed investigations on a pilot scale. On the whole, experiences show that each system is able to supply good quality water that is sufficient to meet crop demands of 2-3 hectares area during *rabi* through the use of sprinklers or of 4-5 hectares of plantation crops through Drip/mini sprinkler irrigation system.

Interpretation of Multielectrode images and depth wise water quality

Multi-electrode imaging studies has been carried out in 24 locations of Bapatla coast, obtained the resistivity images and interpreted to a depth of 11.5 m in collaboration with National Geophysical Research Institute. The aquifers at different locations from sea coast were classified into four depth groups, i.e. dry sand (top layer), fresh water having 0-2 dS m^{-1} salinity, marginal water having 2- 4 dS m^{-1} and saline water having more than 4 dS m^{-1} and mapped for feasible usage of ground waters as shown in Appendix I

Hydraulic performance of skimming wells

Measurements on the area of influence of wells installed at Reddypalem showed that the collector line with 6" dia. receive water from a surrounding of 50 m radius on either side of the sump well and a spacing of 100 m between two well collectors is to be maintained. The bidirectional water discharge rate into sump depended upon the hydraulic head over the collector line and soil hydraulic conductivity (Table 1). The hydraulic conductivity value estimated for sandy soils of Reddypalem dominated with coarse sand is 20.04 m/day and for sandy soil dominated with fine sand is 7.06 m/day.

Table 1. Collector well discharges at different hydraulic heads in coarse and fine textured soils at Timmareddypalem

S. No	Hydraulic Head (m)	Discharge in Liters per second	
		Sandy soil dominated with coarse sand	Sandy soil dominated with fine sand
1	0.4	4.86	2.71
2	0.6	7.34	4.09
3	0.8	9.86	5.50
4	1.0	12.42	6.90
5	1.2	15.01	8.91

The major factors that influence design criteria are: a) Installation depth to avoid entry of underground saline water (Upconing); b) Collector line spacing as a function of their length and soil hydraulic conductivity.

Shallow tube wells and multi-strainer tube wells

During the recent past, innovative and progressive farmers tried to install shallow depth (4.5 - 6.0 m deep) low discharge tube wells and multi-strainer bore wells with varying designs in Andhra Pradesh and Tamil Nadu to tap the top layered shallow depth fresh water. These systems performance being assessed by AICRP Saline Water Scheme, Bapatla in terms of yield, quality, underground quality changes using state of art multi-electrode imaging techniques and economic viability and social acceptability survey.

Upconing response conceptual frame work for fresh water harvesting for different locations of Bapatla coast was developed. The maximum permissible saline upcone (Z max) can be fixed at 50 per cent of Z critical, so that the time at which pumping can be stopped (safer pumping time) at without the saline water harvesting through the structure was calculated. Based on the depth-wise water quality, saline ground water upconing parameters with safe pumping hours of 0 to 13 hours for 8 different locations of Bapatla Coast observed for 6 m deep tube wells with 4 lps discharge rate and presented in Table 2.

Table 2. Upconing parameters for different locations with safe pumping time under existing watertable conditions

Location	Upconing parameters				Safe pumping time (Hours)
	Z critical (m)	Zmax (m)	Reduction factor at critical level (F_{cr})	Reduction factor for permissible upconing (Fs)	
Muthaipalem	2.00	1.00	0.790	0.5	1.0
Bapatla	2.00	1.00	0.815	0.5	1.0
Padisonpet	3.60	1.80	0.619	0.5	6.0
Karlapalem	3.20	1.60	0.419	0.5	11.0
T R Palem	1.90	0.95	0.732	0.5	1.0
RBV Palem	3.20	1.60	0.363	0.5	5.0
Kothapalem	4.50	2.25	0.191	0.5	13.0
P V Palem	0.50	0.25	-	0.5	Not feasible

Performance of different skimming structures

- Multi-electrode imaging studies carried-out under shallow vertical tube well (Fig. 1) and horizontal skimming well (Fig. 2) with pumping revealed that there is abnormal resistivity reduction invertical tube well area. The reduction in resistivity indicates the degrading of water quality and there is a possible upconing of saline waters. In case of horizontal skimming well area negligible change in resistivity, which proves that there is no upconing and horizontal skimming is safe method of harvesting ground water.
- Harvested water quality analysis was carried-out under different skimming structures. There was little change in the salinity of water harvested through the traditional doruvus with pot irrigation (0-1.5%), traditional doruvu with 1 hp pumping unit (1.5 – 5.9%), skimming well with horizontal collectors (1.5 – 5.6%). In case of shallow tube well, a gradual increase (8.1- 46.0%) in salinity of pumped waters with pumping time was observed. In case of multi-strainer well a moderate rise of salinity (3.5 to 13.7%) was observed.

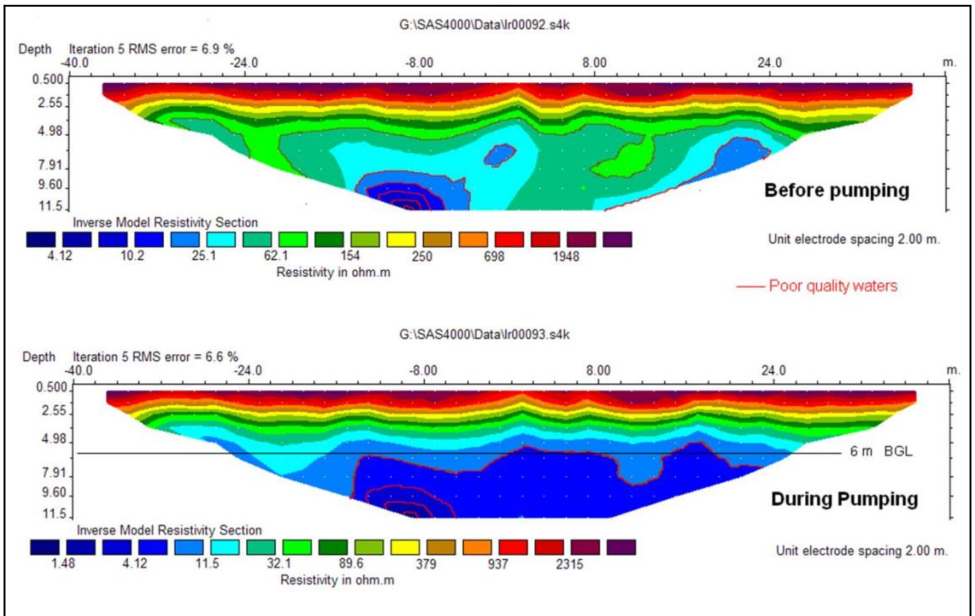

Fig. 1 : Resistivity image profile near a shallow tube well before and during pumping at Bapatla

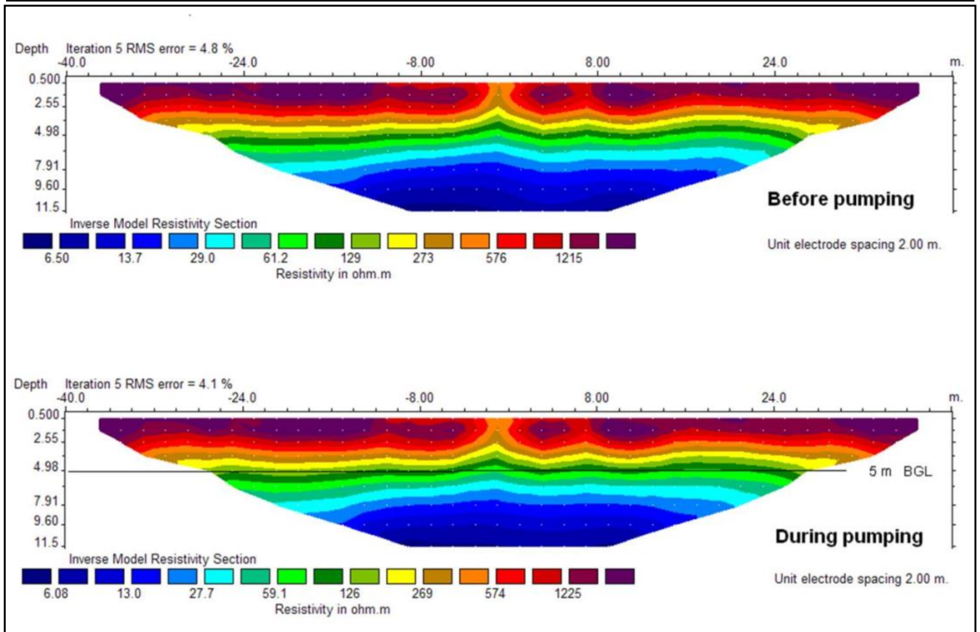

Fig. 2 : Resistivity image profile above collector lines of a skimming well before and during pumping at Bapatla

- The economic appraisal of the improved technologies at farmers level – using discounting techniques revealed that skimming well with horizontal collectors contributes higher benefit cost ratio (2.15) to the farmers followed by multi-strainer tubewell (1.96) and shallow tube well(1.35) technologies. Based on Garretts raking test, farmers preference for different skimming technologies was analysed. Skimming well with collectors was ranked first by the sample farmers followed by the multi-strainer tube wells and shallow tube wells over traditional method.

- Future prospects of skimming wells in Andhra Pradesh reveal that investment of Rs.3000 million on skimming can generate returns worth of Rs.6650 million (Table 3).

Table 3. Future prospects of shallow water harvesting wells in the coastal belt of Andhra Pradesh (Based on 2019 prices)

Total coastal sandy soils of Andhra Pradesh	:	1.74 lakh ha.
Estimated coastal sandy soils with 0.5- 3.0 m fresh water	:	0.70 lakh ha.
No of shallow depth water harvesting wells feasible without water quality changes	:	35000
Cost of each well system including conveyance / Sprinkler system	:	Rs. 120000/- each
Expected additional out put with each well system including labour savings compare to conventional *doruvu's*	:	Rs. 38200/- per year
Expected cost of the wells with execution overheads - One-time investment	:	Rs. 462 crores
Annually expected additional returns from 35000 wells	:	Rs 133.7 crores
Life time of the project	:	25 years
Net present worth of returns anticipated from the project	:	Rs. 998 crores
Realization of investment	:	4-5th year

Conclusions

The shallow fresh water floating over the saline water is the life line of the coastal regionand any overexploitation of this resource may lead to the disastrous consequence viz., salineaquifer. To avoid this situation the withdrawals from the aquifer should be commensurate withits seasonal recharge.

From the point of view of preventing salt water intrusion into the inland fresh wateraquifer and in order to keep the saline fresh water interface into coastal aquifers far below thecritical levels, the skimming well with horizontal collector system be a viable solution. Also, this system serves the purpose of harvesting fresh water or relatively fresh water for stabilizing cropproduction in a profitable way in the coastal belts.

Though the skimming well technology has been accepted and adopted by few farmers ofcoastal sandy soils of Andhra Pradesh, its further adoption by the small and marginal farmers isconstrained due to non availability of funds for installation of the these wells, purchase of oilengine/electric motor and sprinkler/drip systems. If the subsidy/loans for installation are provided by theGovernment of India, the technology can be adopted not only in Andhra Pradesh, but also incoastal parts of Tamil Nadu, Orissa and West Bengal states.

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Appendix-I

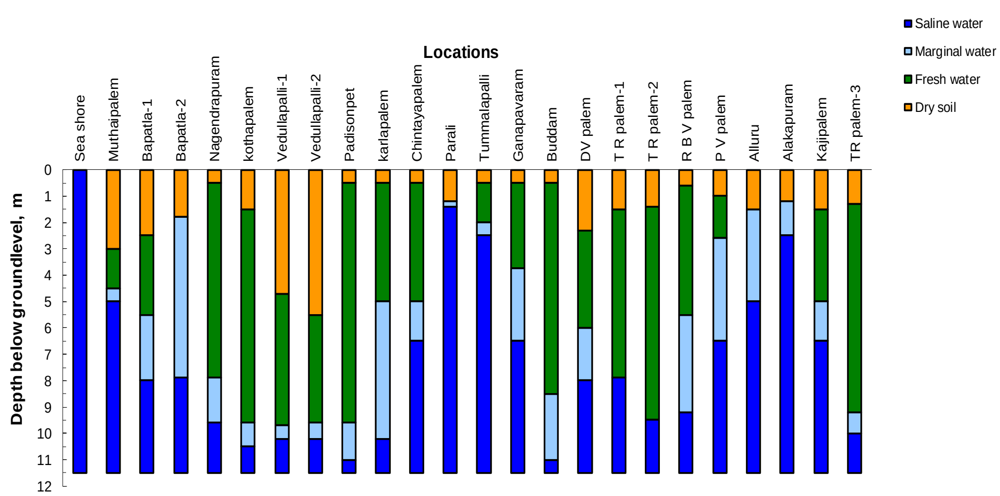

Fig. 1 : Depthwise water quality classification by Multi-electrode imaging

Recent Concepts on Diagnosis, Treatment and Management of Backyard Poultry

Dr. S. Shakila

Department of Poultry Science, College of Veterinary Science, S.V. Veterinary University, Tirupati – 517 502 A.P.

Rearing of backyard birds in small numbers in backyards is a source of livelihood mostly in rural areas. It contributes an important role especially for the socio-economic development of the weaker section of the society in India. Backyard birds farming is a low input business in terms of feeding cost, labour cost, shelter provision and health care compared to commercial poultry farming. There is a greater scope for backyard poultry rearing to meet the ICMR recommendations for eggs about 182 and meat 11 kg per head per year.

Advantages of backyard birds farming

1. Low input cost and the birds can easily sustain on kitchen waste, worms, insects, weeds, grains, rice etc.
2. Products from rural poultry farming fetches high price compared to commercial poultry Farming.
3. Lessens protein malnutrition in susceptible groups like pregnant women, feeding mothers and children in rural areas.
4. It provides employment to the rural small scale and marginal farmers.
5. Aids in enhancing the soil fertility in backyards (15 chickens produce 1-1.2 kg of manure/ day).
6. Birds reared under free range conditions give eggs and meat of low cholesterol concentration compared to those produced under intensive poultry farming.
7. Resistance to diseases, better adaptability to extreme climatic conditions, can thrive better even on poor management.

Selection of Backyard / Native birds

The following are important native / desi breeds may be selected

1. **Aseel:** It is the most popular breed of India and it is known for aggressive behavior, fighting quality and majestic gait. Its home tract is coastal Andhra Pradesh, Chhattisgarh states.
2. **Kadaknath:** The home tract of this breed is Madhya Pradesh This breed is also known as '*Kalamashi'*in Hindi due to its black coloured flesh.
3. **Ghagus:** Its native tract is located in Karnataka and border areas of Andhra Pradesh. It is a medium sized bird with good mothering ability.
4. **Nicobari:** Native of Nicobar group of Islands. They are brownish matty coloured, medium sized birds with compact body, short legs and thick necks.
5. **Miri:** These are small sized compact birds reared mainly by Miri (Mising) tribes of Assam.
6. **Mewari:** The home tract of this breed is Mewari region of Rajastan.

7. **Hansli:** This breed is predominantly reared in *Mayurbhanj* and some parts of *Keonjhar* district of Odisha. Birds of this breed phenotypically resemble to Aseel breed.
8. **Uttara:** It is the latest breed to be registered in breed registry of NBAGR, Karnal. Its native tract is located in hill districts of Uttarakhand state. It has black coloured plumage, feathered shanks.

Rural poultry farming primarily involves above mentioned backyard birds with low productivity may be below 100 eggs per year but today a number of genetically improved varieties of indigenous birds are available which are suitable for rearing in rural areas. The following are the improved rural birds can be selected for better performance and they are developed by Director of Poultry Research, Hyderabad, AICRP on Poultry breeding Centres, and Veterinary Universities of different states in the country.

Advantages of improved backyard birds than indigenous chicken

1. Attractive feather pattern
2. Longer shanks help to run faster
3. Hardiness
4. Higher body weight
5. Produces more number of medium sized eggs
6. Produces brown coloured eggs as that of Backyard birds
7. Produces lean or low fat content meat
8. Higher survivability

S. No.	Type	Name of the improved backyard birds
1	Egg type	Rajasree, Vanashree, Srinidhi, krishilayer, Swarna dhara, CARi gold, Gramalakshmi, Grama Priya, Kalingabrown, Krishna-J
2	Meat type	Krishi bro, Giriraja, CARI Nirbheek, CARi Shyama
3	Duel type	Rajasri, Vanaraja, Gramasree, Triveni, Krishna priya, Pratapdhan, Himsamridhi, Jharsim, Hitcari, Nandanam, UPcari, Nicorock, Nishibari, Yamuna

Performance of some improved backyard birds

Trait	Backyard	Rajasree	Vanaraja	Gramapriya	Sreenidhi
Liveability, %	80-90	96	98	>95	98
body wt. at 8 wks (g)	600-700	500-550	750-850	400-450	600-650
Age at first egg laid (days)	200-210	165	175-180	160-165	150-155
Egg production	60-80	160-170	160	160	220-230
Egg wt. (g)	45-50	55	57-58	55-60	54-55
Adult wt. (kg)	1.5 to 2.5	1.5 to 1.75	2.0-2.5	1.6-1.8	1.9-2.1

Management practices

The chicks can be reared upto 6 weeks in sheds or in pens throughout the day and night and after 6 weeks of age, they are sent to outside during day time and can be kept in shelters during the night.

Housing management

Under free range system: There should be provision of open space for chickens to roam around the day time and a night shelter can be constructed with low cost and locally available materials like bamboo, wooden planks, polythene sheets, etc. Provide adequate space per bird and avoid overcrowding.

Under confinement system: Generally, in the shed 2 sq.ft area per bird should be provided. A shed may be constructed with 25 ft width and height should be 10-12 feet in the middle and 8-10 feet on the sides. Side wall height of 2-3 feet. Remaining height may be covered with chicken mesh. The length is decided based on the number of birds reared.

Rearing of chicks (0-6 weeks)

Brooding is the important managemental practice to care new born chicks during initial 4-6 weeks of age. Brooder house, feeders, drinkers, hovers should be disinfected before arrival of chicks. The brooding arrangement can be made either on deep litter system or in cage system as per available facilities. Artificial heat is provided by any type of brooders like electrical bulb, Infra-red bulb or gas brooders. The temperature during the first week should be 95°F later decrease the temperature about 5°F per week like that temperature is maintained till room temperature attains by 4-6 weeks.

In deep litter system a 2-3 inch clean litter material is placed uniformly. Initially spread newspaper over litter material for 2-3 days to prevent chicks from eating litter material which may choke their throat causing death due to suffocation. Arrange feeders and drinkers alternatively and the movement of chicks can be restricted near the heat source with the help of the chick guard. The diameter of chick guard may be increased daily as the age of the birds is increasing daily. Newspapers can be removed on 6th day and the chick guard may be removed by 10th day onwards. Before placing the chicks on newspapers, the beak should be dipped in drinkers and they are released on the papers. Initially in the water glucose/jaggery/ electrolytes may be added for 2-3 days.

Floor space

The chick should be provided sufficient feeding, watering and floor space (Table 1). Otherwise overcrowding results in stress and mortality in birds.

Table 1. Space requirement for poultry

Age (Weeks)	Floor space (sq. ft)	Feeding space (cm)	Watering space (cm)
0-4	0.5	2.5	1.5
4-8	1.0	5.0	2.0
8-12	2.0	6.5	2.5

On first day crushed maize may be sprinkle on newspaper and 2nd day onwards balanced feed with minerals, vitamins and anticoccidial drugs can be fed. Mostly chicks need 2,400 kcal ME, 16% protein, 0.77% lysine, 0.36% methionine, 0.35% available phosphorus and 0.7% calcium. The feed can be prepared by using local feed ingredients as Table 2 or commercial feed can be fed to the birds.

Rearing of birds after 6 weeks

fter six weeks of rearing, they can be let outside for foraging. They can eat grains, small insects, earthworms, kitchen wastes etc. Appropriate physical growth is very important in this period. Under free- range conditions generally the birds meet their protein requirement through scavenging, but, the energy deficiency is common in birds. So, to prevent this condition feeding the birds with some locally available cereals (like maize, bajra, jowar, broken rice) may be given. Allow them to roam freely in the open space of free range compound. In evening time, feeding is practiced at particular time, so that birds will come to home regularly after foraging in the day is a habituated. The following time schedule for feeding the birds may be practiced.

Time of feeding	Type of feed
Morning 6-7 A.M.	2 or 3 varieties of grains/cereals like bajra, broken rice, jowar, Ragi etc.
9.00 A.M.	Chopped green leaves
12-12.30 P.M.	Rice bran or mash feed
Evening 5-6 P.M.	Spreading of grains or cereals

During the growing stage, feed with 15-16% of protein content is necessary. Deworming should be done every month regularly otherwise growth will be affected. Vaccines which recommended during this stage are to be given as per schedule.

Table 2. Feed ingredients for balanced ration to the birds

Ingredient	Quantity (Approx. kgs)
Maize/ Bajra /Ragi	50
Soybean/groundnut cake/sunflower meal	30
Rice bran/Deoiled rice polish	17
Mineral mixture	3

When hens start to lay the eggs, provide nests with clean nesting material for laying of eggs. Nests can be in the fenced area or in the shelter itself. If birds are reared in large number, good quality layer diet and for aging etc. are to be provided for better egg production. The calcium can be supplemented by adding the shell grit /lime stone /oyster shell in the diet etc. In this period, they need a diet with 18-19% of protein content. Lighting is also important about 16 hrs for laying of eggs in the sheds.

During summer, it is better to feed wet mash and it is fed at the afternoon to the birds and it should not be stored for longer time. Butter milk also added in the drinking water to prevent heat stress. Water should be available always for drinking and it should be cool and clean.

Common Diseases

The following diseases are commonly encounter in the backyard birds

Viral diseases : Fowl pox, Ranikhet and Marek's IBD and ALC

Bacterial diseases **:** Salmonellosis, E.Coli infections and Infectious coryza

Other diseases **:** Coccidiosis**,** Nematodes and Tape worm infestations.

To prevent viral diseases the following vaccination schedule is adopted:

S. No.	Name of the vaccine	Age	Route of administration
1	Marek's	Ist day	0.20 ml/bird - S/c
2	F_1	7th day	one drop oral
3	IBD vaccine	14th day	one drop oral
4	lasota	28th day	Through drinking water
5	Fowl pox	36-42 day	0.20 ml /bird S/C
6	R_2B	8th week	0.50 ml S/C or I/M and it is repeated every six months

Before doing deworming or vaccination, vitamins or mineral supplements are to be given in water for 2-3 days to reduce stress in birds. Deworming is also must before vaccination for improved backyard birds.

The farmers will be benefitted much if, the above management practices are followed properly in rearing the improved backyard birds and thereby their socio-economical status will also be improved.

Rajasri birds

Vanaraj bird

Aseel

Nandanam

Gramalakshmi

Brooding

Biofertilizers in Soil Health Management and Suatainable Crop Productivity in Coastal Agriculture

R. Lakshmipathy, P.R.K. Prasad and S. Vinod Babu

Agricultural Research Station, Amaravathi, Andhra Pradesh. India
Corresponding author: r.lakshmipathy@angrau.ac.in

In recent years, the growing adoption of organic farming has resulted in a more sustainable approach towards agriculture as it emphasises on adopting environmentally benign practices to ensure food security while protecting and nurturing soil biodiversity. Stakeholders are adopting various strategies to make organic and sustainable agriculture mainstream; one of the key ones being the use of bio-based fertilizers or bio-fertilizers to provide optimum nutrients to crop and enhance soil potency. However, intensive farming emphasizes in using hybrid seeds and high yielding varieties that are highly responsive to large doses of chemical fertilizers and irrigation. Indiscriminate use of synthetic fertilizers has led to pollution and contamination of soil and water basins in coastal areas.

Also, it is estimated that by 2020, to achieve the targeted production of 321 million tons of food grain, the requirement of nutrient will be 28.8 million tons, while their availability will be only 21.6 million tons being a deficit of about 7.2 million tons, thus depleting feedstock/fossil fuels (energy crisis) and increasing cost of fertilizers which would be unaffordable to small and marginal farmers, thus intensifying the depleting levels of soil fertility due to widening gap between nutrient removal and supplies.

Chemical fertilizers which are now being used extensively since the green revolution have depleted soil health by making the soil ecology non - inhabitable for soil micro flora and micro fauna which are largely responsible for maintaining soil fertility and providing some essential and indispensable nutrients to plants in coastal and other adjoining areas. Biofertilizers are the products containing one or more species of microorganisms which have the ability to mobilize nutritionally important elements from unusable to usable form through biological processes such as nitrogen fixation, phosphate solubilisation, excretion of plant growth promoting substances or cellulase and other biodegradable biochemicals in soil. The role of biofertilizers in coastal agriculture assumes special significance, particularly in the present context of increased cost of chemical fertilizer and their hazardous effects on soil health.

Biofertilizers: Classification of Biofertilizers based on nutrients supply

At present times, there is a growing concern about environmental hazards of intensive farming to soil health and interest towards organic farming, natural farming and sustainable agriculture biofertilizer has become an important component. In view of the above stated facts, the long term use of bio-fertilizers proves to be economical, eco-friendly, more efficient, productive and accessible to marginal and small farmers over chemical fertilizers.

Several microorganisms and their association with crop plants are being exploited in the production of biofertilizers. They can be grouped in different ways based on their nature and function.

Different types of Biofertilizers

S. No.	Types of biofertilizers	Examples
	N2 fixing Biofertilizers	
1.	Free-living	*Azotobacter, Beijerinkia, Clostridium, Klebsiella, Anabaena, Nostoc, Occilotoria, Tolypothrix (Cyanobacteria)*
2.	Symbiotic	*Rhizobium, Frankia, Anabaena azollae*
3.	Associative Symbiotic	*Azospirillum*
	Phosphorous Solubilizing Biofertilizers	
4.	Phosphate solubilizing Bacteria (PSB)	*Bacillus megaterium* var. *phosphaticum, Bacillus subtilis, Bacillus circulans, Pseudomonas striata*
5.	Fungi Phosphate solubilizing (PSF)	*Penicillium sp, Aspergillus awamori*
	Phosphorous Mobilizing Biofertilizers	
6.	Arbuscular mycorrhiza	*Glomus sp., Gigaspora sp., Acaulospora sp., Scutellospora sp.* & *Sclerocystis sp.*
7.	Ectomycorrhiza	*Laccaria sp., Pisolithus sp., Boletus sp., Amanita sp.*
	Potash releasing biofertilizers	
8	Potash Releasing bacteria	*Bacillus mucilaginosus, B. edaphicus, B. circulans, Acidothiobacillus ferrooxidans, Paenibacillus spp.*
	Biofertilizers for Micro nutrients	
9.	Silicate and Zinc solubilizers	*Bacillus* sp.
10.	Other PGPRs	*Pseudomonas fluorescens*

Rhizobium: Rhizobium is a soil habitat bacterium, which colonizes legume roots and fixes atmospheric nitrogen symbiotically. The morphology and physiology of Rhizobium vary from free-living condition to the bacteroid of nodules. They are the most efficient biofertilizer as per the quantity of nitrogen fixed concerned. They have seven genera and are highly specific to form nodule in legumes, referred as cross inoculation group.

Azotobacter: Of the several species of *Azotobacter*, *A. chroococcum* happens to be the dominant inhabitant in arable soils capable of fixing N_2 (2-15 mg N_2 fixed /g of carbon source) in culture media. The bacterium produces abundant slime which helps in soil aggregation. The numbers of *A. chroococcum* in Indian soils rarely exceeds 105/g soil due to lack of organic matter and the presence of antagonistic microorganisms in soil.

Azospirillum: *Azospirillum lipoferum* and *A. brasilense* (*Spirillum lipoferum*in earlier literature) are primary inhabitants of soil, the rhizosphere and intercellular spaces of root cortex of graminaceous plants. They develop associative symbiotic relationship with graminaceous plants. Apart from nitrogen fixation, growth promoting substance production (IAA), disease resistance and drought tolerance are some of the additional benefits of inoculation with *Azospirillum*.

Cyanobacteria: Both free-living as well as symbiotic cyanobacteria (blue green algae) have been harnessed in rice cultivation in India. Once so much publicized as a biofertilizer for rice crop, it has not presently attracted the attention of rice growers all over India. The benefits due to algalization could be to the extent of 20-30 kg N/ha under ideal conditions but the labour oriented methodology for the preparation of BGA biofertilizer is in itself a limitation.

Azolla: *Azolla* is a free-floating water fern that floats in water and fixes atmospheric nitrogen in association with nitrogen fixing blue green alga *Anabaena azollae*. *Azolla* either as an alternate nitrogen sources or as a supplement to commercial nitrogen fertilizers. *Azolla* is used as biofertilizer for wetland rice and it is known to contribute 40-60 kg N/ha per rice crop.

Phosphate solubilizing microorganisms* (PSM)*: Several soil bacteria and fungi, notably species of *Pseudomonas, Bacillus, Penicillium, Aspergillus etc*. secrete organic acids and lower the pH in their vicinity to bring about dissolution of bound phosphates in soil. Increased yields of wheat and potato were demonstrated due to inoculation of peat based cultures of *Bacillus polymyxa* and *Pseudomonas striata*.

AM fungi: The transfer of nutrients mainly phosphorus and also zinc and sulphur from the soil *milleu* to the cells of the root cortex is mediated by intracellular obligate fungal endosymbionts of the genera *Glomus, Gigaspora, Acaulospora, Sclerocysts* and *Endogone* which possess vesicles for storage of nutrients and arbuscles for funnelling these nutrients into the root system. By far, the commonest genus appears to be *Glomus*, which has several species distributed in soil.

The improvement of P nutrition of plants has been the most recognized beneficial effect of mycorrhizas. It is also reported that the AM- fungi also increases the uptake of K and efficiency of micronutrients like Zn, Cu, Fe etc. By secreting the enzymes, organic acids can makes fixed macro and micronutrients mobile and as such are available for the plant. Better water relation and drought tolerance: AM fungi play an important role in the water economy in the plants. Their association improves the hydraulic conductivity of the root at lower soil water potentials and this improvement is one of the factors contributing towards better uptake of water by plants. Improved Soil structure (A physical quality): Mycorrhizal fungi contributes to soil structure by growth of external hyphae into the soil to create a skeletal structure that holds soil particles together, creation of conditions by external hyphae that are conducive for the formation of micro aggregates, enhancement of micro aggregates to form macro aggregates and directly tapping carbon resources of the plant to the soils. Enhanced phytohormone activity: The activity of phytohormones like cytokinin and indole acetic acid (IAA) is significantly higher in plants inoculated with AM. Higher hormone production results in better growth and development of the plant. Crop protection (interaction with soil pathogens): AM inoculation considerably increases production and activity of phenolic and phytoalexin compounds due to which the defense mechanism of plant becomes stronger there by imparts the resistance to plants.

***Silicate solubilizing bacteria (SSB)**:* Microorganisms are capable of degrading silicates and aluminium silicates. During the metabolism of microbes several organic acids are produced and these have a dual role in silicate weathering. They supply H^+ ions to the medium and promote hydrolysis and the organic acids like citric, oxalic acid, Keto acids and hydroxy carbolic acids which form complexes with cations, promote their removal and retention in the medium in a dissolved state.

***Plant growth promoting rhizobacteria (PGPR)**:* The group of bacteria that colonize roots or rhizosphere soil and beneficial to crops are referred to as plant growth promoting rhizobacteria (PGPR). The PGPR inoculants promote growth through suppression of plant disease (termed Bioprotectants), improved nutrient acquisition (termed Biofertilizers), or phytohormone production (termed Biostimulants). Species of *Pseudomonas* and *Bacillus* can produce as yet not well characterized phytohormones or growth regulators that cause crops to have greater amounts of fine roots which have the effect of increasing the absorptive surface of plant roots for uptake of water and nutrients. These PGPR are referred to as Biostimulants and the phytohormones they produce include indole-acetic acid, cytokinins, gibberellins and inhibitors of ethylene production.

Application of biofertilizers

Seed treatment: The seeds are uniformly mixed in the slurry of the inoculants and then dried for 30 minutes in shade. The dried seeds are to be sown within 24 hours. 10-15 g of the inoculant is sufficient to treat 1.0 kg of seeds.

Seedling root dip: This method is used for transplanted crops. Four packets (500 g each)/500ml of the inoculant are mixed in 40 litres of water. The root portion of the seedlings is dipped into the mixture for 5 to 10 minutes and then transplanted.

Foliar application: Liquid biofertilizer can be applied through fertigation as well as foliar application to the suitable crop. 500 ml per acre with 100 litres of water.

Main field application: Four packets(500 g)/500 ml bottle of the inoculant are mixed with 200 kg of dried and powdered farm yard manure and then broadcasted in the main field just before transplanting.

Set treatment: This method is recommended generally for treating the sets of sugarcane, cut pieces of potato and the base of banana suckers. Culture suspension is prepared by mixing Four packets (500 g each)/500 ml bottle of bio-fertilizer in 40-50 litres of water and cut pieces of planting material are kept immersed in the suspension for 30 minutes. The cut pieces are dried in shade for some time before planting. For set treatment, the ratio of bio-fertilizer to water is approximately 1:50.

Biofertilizer Recommendation for different crops

Biofertlizer	Formulation	Crops	Dosage	Method of application
Rhizobium	Powder	All pulses & groundnut	10-15 g / kg seed	Seed treatment
	Liquid		10 ml / kg seed	Seed treatment
Azospirillum	Powder	Cereals, Millets, fruit & vegetable crops	2 kg/acre	Soil application along with 200kg FYM/vermicompost
	Liquid		½ litre/ acre	Soil application along with 200kg FYM/vermicompost

Biofertlizer	Formulation	Crops	Dosage	Method of application
Azotobacter	Powder	Vegetables and plantation crops	2 kg/ acre	Soil application along with 200 kg FYM/vermicompost
	Liquid		½ litre/ acre	Soil application along with 200 kg FYM/vermicompost
PSB	Powder	All crops	2 kg/ acre	Soil application along with 200 kg FYM/vermicompost
	Liquid		½ litre/ acre	Soil application along with 200 kg FYM/vermicompost
K releasing bacteria	Powder	All crops	2 kg/ acre	Soil application along with 200 kg FYM/vermicompost
	Liquid		½ litre/ acre	Soil application along with 200 kg FYM/vermicompost
VAM	Powder	Chilli, Maize, plantation crops and nursery based crops	5 kg/ acre	Soil application along with 200 kg FYM/vermicompost

Note: It is advised to apply biofertilizers at the evening time during summer

Advantages of Using Biofertilizers : Some of the advantages associated with biofertilizers include

- They are eco- friendly as well as cost effective
- Their use leads to soil enrichment and the quality of the soil improves with time.
- Though they do not show immediate results, but the results shown over time are spectacular.
- These fertilizers harness atmospheric nitrogen and make it directly available to the plants.
- They increase the phosphorous content of the soil by solubilising and releasing unavailable phosphorous.
- Biofertilizers improve root proliferation due to the release of growth promoting hormones.
- Microorganism converts complex nutrients into simple nutrients for the availability of the plants.
- Biofertilizer contains microorganisms which promote the adequate supply of nutrients to the host plants and ensure their proper development of growth and regulation in their physiology.
- They help in increasing the crop yield by 10-25%.
- Biofertilizers can also protect plants from soil born diseases to a certain degree.

Amount of Nutrients Fixed/supplied by Biofertilizers in Various Crops

Microorganisms used as	Nutrient fixed (kg/ha/year)	Beneficiary crops
Rhizobium	50 to 300 kg N / ha	Groundnut, Soybean, Redgram, Greengram, Black-gram, Lentil, Cowpea, Bengal-gram and Fodder legumes
Azotobacter	0.026 to 20 kg N / ha	Cotton, Vegetables, Mulberry, Plantation Crop, Rice, Wheat, Barley, Ragi, Jowar, Mustard, Safflower, Niger, Sunflower, Tobacco, Fruit, Spices, Condiment, Ornamental Flower
Azospirillum	10-20 kg N /ha	Sugarcane, Vegetables, Maize, Pearl millet, Rice, Wheat, Fodders, Oil seeds, Fruit and Flower
Blue Green Algae	25 kg N /ha	Rice, banana
Azolla	900 kg N /ha	Rice
Phosphate solubilizing bacteria and fungi	Solubilize about 50-60% of the fixed phosphorus in the soil	All Crops (nonspecific)

Some of the constraints in Biofertilizer Technology

Though the biofertilizer technology is a low cost, eco-friendly technology, several constraints limit the application or implementation of the technology. The constraints may be

- Technological constraints like unavailability of good quality carrier material and lack of qualified technical personnel in production units.
- Infrastructural constraints like lack of essential equipments, power supply, etc.
- Financial constraints like non-availability of sufficient funds and problems in getting bank loans.
- Environmental constraints like seasonal demand for biofertilizers, simultaneous cropping operations and short span of sowing/planting in a particular locality, etc.
- Human resources and quality constraints like lack of technically qualified staff in the production units, lack of suitable training on the production techniques.
- Unawareness on the benefits of the technology due to problem in adoption of the technology by the farmers due to different methods of inoculation, no visual difference in the crop growth immediately as that of inorganic fertilizers.
- Marketing constraints like non availability of right inoculant at the right place at the right time, lack of retail outlets or the market network for the producers.

- The different constraints in one way or the other affect the technique at production, or marketing or usage.

Conclusions

Biofertilizers being essential components of organic farming play a vital role in maintaining sustainable soil fertility and productivity by fixing atmospheric di-nitrogen, mobilizing fixed macro and micro nutrients in the soil into forms available to plants. Currently there is a gap of ten million tons of plant nutrients between removal of crops and supply through chemical fertilizers. In this context both the cost and environmental impact of chemical fertilizers, excessive reliance on chemical fertilizers is not practicable in the long run hence there is a need for alternative source. In this context, biofertilizers would be the viable option for farmers to use biofertilizers for enhancing the productivity per unit area.

Hence, focus should be on the production of efficient and sustainable bio-fertilizers for crop plants. In view of this, it will be necessary to undertake short-term, medium, and longterm research, in which soil microbiologists, agronomists, plant breeders, plant pathologists, and even nutritionists and economists must work together. The most important and specific research needs should highlight on following points: 1. Selection of effective and competitive multi-functional bio-fertilizers for a variety of crops. 2. Quality control system for the production of inoculants and their application in the field, to ensure and explore the benefits of plant- microorganism symbiosis. 3. Study of microbial persistence of biofertilizers in soil environments under stressful conditions 4. Agronomic, soil, and economic evaluation of biofertilizers for diverse agricultural production systems. 5. Transferring technological know-how on biofertilizer production to the industrial level and for optimum formulation.

Soil Resource Inventory of Coastal Soils: A Case Study in Chillakur Mandal of SPSR Nellore District in Andhra Pradesh

M.V.S. Naidu*, U. Vedadri, G. Sivanagaraju, G.P. Leelavathy, K.V. Naga Madhuri and P.R.K.Prasad

Corresponding author: mvsnaidu66@gmail.com

Soil is a finite and non-renewable resource that determines the feasibility for implementation of agricultural developmental programmes in any nation on the planet of earth. Timely and reliable information of soils with respect to their nature, extent, spatial distribution, potentials and limitations is very crucial for optimum utilization of finite soil resource on sustainable basis. Standard soil survey helps to gather information about soils in a systematic manner regarding their genesis, extent and characteristics to assess their potentials and limitations for specific purpose. Quantitative information and spatial distribution of soil properties are among the main pre-requisites for achieving sustainable land management. The accuracy of soil information determines, to a large extent, the reliability of land resources for management decisions (Mermut and Eswaran 2001). Soils differ in their morphology, physicochemical characteristics, inherent productivity and fertility and their responses to management practices. Thus, an investigation was taken up to study the soils of Chillakur mandal representing coastal soils SPSR Nellore district in particular and Andhra Pradesh in general for genesis, classification and evaluation and also for suggesting sustainable land use plan and soil -site suitability for commonly growing crops of the area.

Materials and Methods

Geographically, Chillakur mandal lies in between 14°01′ and 14°12′ N latitudes and 79°51′ and 80°04′ E longitudes with an elevation ranging from 3- 41 (m) MSL. The study area consists of granite-gneiss and alluvium parent material. The climate belongs to semi-arid monsoonic with distinct summer, winter and rainy seasons. The mean annual rainfall recorded for the last ten (2006-2015) years is 1113 mm of which 90% was received during July to December. The mean annual temperature was 28.7°C with a mean summer temperature of 30.6°C and a mean winter temperature of 25.2°C. The maximum temperature recorded for last 10 years is 40.1°C and the minimum temperature is 18.1°C in the months of May and December, respectively. The soil moisture regime has been computed as ustic and soil temperature regime as isohyperthermic. The natural vegetation comprises of *Acacia nilotica, Parthenium hysterophorus, Cynodon dactylon, Azadirachta indica, Calotropis gigantia, Cyprus rotundus, Pongamia pinneta, etc.*

A reconnaissance soil survey was conducted using Survey of India toposheet on 1:50,000 scale as per procedure outlined by AIS & LUS (1970). On the basis of soil correlation exercise seven typical pedons *viz.*, four pedons in plains and three in uplands were identified in the study area. The morphological properties of these seven master pedons were studied in the field as per the procedure outlined in Soil Survey Manual (Soil Survey Division Staff 2000). Horizon-wise soil samples were collected and characterized for important physical, chemical properties and available nutrient status using standard procedures The soils were classified taxonomically (Soil Survey Staff 2014). Considering limitations and potentials of the soils, land capability classification was evaluated up to sub-class level (Klingebiel and Montgomery 1966) and based on that a suitable land use plan has also been suggested. These pedons were selected for evaluation and their suitability assessed using limitation method regarding number and intensity of limitations (Sys *et al.*, 1991; Sys *et al.*, 1993).

Results and discussion

Soil morphology

The solum depth varied from deep to very deep. These soils were poorly drained to well-drained. The colour varied from yellowish red to dark reddish brown in pedons1, 3 and 4, brown to yellow in pedons 5, 6 and 7 and pale brown to dark yellowish brown in pedon 7. The soil colour appears to be the function of chemical and mineralogical composition) as well as textural make up of soils as conditioned by topographic position and moisture regime. The coastal soils of Chillakur mandal showed wide textural variation (sand to clay loam). This wide textural variation might be due to variation in parent material (granite-gneiss to alluvium), topography, *in-situ* weathering and translocation of clay by eluviations (Sireesha and Naidu 2013). The structure of the soils is crumb, sub-angular blocky and angular blocky. The blocky structure *i.e.* angular and sub-angular blocky were attributed to the presence of higher quantities of clay fraction. The crumb structure in the pedons 4 and 5 might be due to continuous of addition of organic matter through vegetation.

The consistency of the soils varied from soft to very hard (dry), loose to very firm (moist) and non-sticky and non-plastic to very sticky and very plastic (wet). Presence of sticky and plastic to very sticky and very plastic, firm to very firm and slightly hard to very hard consistency in wet, most and dry conditions, respectively in the pedons of 2 and 5 may due to dominance of smectite clay mineral. Pedons 2, 5 and 6 exhibited cambic (Bw) sub-surface diagnostic horizons while pedons 1, 3, 4 and 7 do not have any diagnostic horizon. Strong to violent effervescence with dilute HCl was observed in pedon 2 indicating presence of $CaCO_3$ in this soil. The horizon boundaries are clear to diffuse in distinctness and smooth to wavy in topography.

Soil characteristics

Physical characteristics

Particle size analysis data revealed that the clay content varied from 5.20 to 38.30%. The increase in clay content in Bw horizon of pedons 5 and 6 was primarily due to *in-situ* weathering of parent material. More or less increase in clay content with depth was noticed in pedons 1, 2, 3, 5 and 6, which might be due to variability of weathering in different horizons and translocation of clay from upper to lower horizons. Silt content in general exhibited an irregular trend with depth, this irregular distribution of silt might be due to variation in weathering of parent material or *in-situ* formation (Devi *et al.*, 2015). Sand constitutes the bulk of mechanical fractions, which could be attributed to the siliceous nature of parent materials.

The bulk density of different pedons varied from 1.22 to 1.85 Mg m^{-3} and had shown more or less an increasing trend with depth due to low organic matter and less aggregation. These findings were in harmony with findings of Sireesha and Naidu (2013). Low bulk density in surface soils was due to higher organic matter content and this is evident from the negative correlation ($r = -0.329$) of bulk density with organic carbon. Water holding capacity of different pedons varied from 13.8 to 46.2%. These variations were due to the difference in depth, clay, silt and organic carbon content. Furthermore, low water holding capacity in sandy soils was due to high sand and less clay content as evident by significant and negative correlation ($r = -0.721$) between water holding capacity and sand. The irregular trend of water holding capacity with depth was due to the illuviation and eluviation of finer fractions in different horizons.

Physical and chemical characteristics

All the pedons were slightly acidic to moderately alkaline in reaction, this wide variation was attributed to the nature of the parent material, leaching, presence of calcium carbonate and exchangeable sodium. The difference between the pH_{KCl} and pH_{H_2O} values ($\Delta pH = pH_{KCl} - pH_{H_2O}$) with large negative value (> -0.4) indicated a high negative surface charge density in these soils. All the pedons had shown low electrical conductivity values ranging from 0.01 to 0.32 dS m^{-1}, indicating non-saline nature. The low electrical conductivity may be due to free drainage conditions which favoured the removal of released bases by percolating and drainage water.

Organic carbon content of these soils was found to be low to medium and varied from 1.2 to 6.1 g kg^{-1}. The organic carbon content decreased with depth in almost all the pedons. This is attributed to the addition of plant residues and farmyard manure at surface horizons than in the lower horizons. The low organic matter content in the soils might also be due to the prevalence of tropical condition, where the degradation of organic matter occurs at a faster rate coupled with low vegetation cover, thereby leaving less organic carbon in the soils

The CEC in all the pedons estimated by ammonium acetate extract varied from 4.70 to 25.52 c mol(p^+) kg^{-1} soil which corresponds to clay and organic carbon content and also type of clay minerals present in these soils. The CEC increased with increase in clay content of the pedons. The higher values of CEC in upper horizons commensurate with amount of clay (r = 0.773) and organic matter in upper layers. The free $CaCO_3$ ranged from 1.50 to 16.00% and the highest $CaCO_3$ content was noticed in pedon 2, which might be due to semi-arid climate which is responsible for the pedogenic processes resulting in the depletion of Ca^{2+} ions from the soil solution in the form of calcretes. However, in pedons 2 and 5, the $CaCO_3$ increased with depth which might be due to downward movement of calcium and its subsequent precipitation as carbonate and / or decomposition of calcium carbonate. Pedons 3 and 7 showed an irregular distribution with depth, which either may be due to variable nature of geological material that contributed to these soils or rapid leaching of carbonates from the porous sandy soils.

Exchangeable bases in all pedons were in the order of $Ca^{2+} > Mg^{2+} > Na^+ > K^+$ on the exchange complex. The base saturation varied from 53.9 to 98.2%. Low base saturation in sub-soils was due to dominance of exchangeable complex while comparatively high base saturation in surface horizons may be due to continuous addition of bases from leaf litter and also due to high Ca^{2+} followed by Mg^{2+}, Na^+ and K^+ The ratio between Ca and Mg ranged from 0.81 to 3.36 and narrower Ca^{2+}/Mg^{2+} ratio was due to suppression of Ca solubility, substitution of Mg^{2+} or Ca^{2+} by plants and recycling of unusual amount of Mg. Similar results were reported by (Raghuwanshi *et al.* 2011). The ratio between CEC and clay ranged from 0.20 to 0.90 and the CEC: clay ratio was useful in the identification of clay mineralogy

Soil genesis

Soil profiles exhibited distinctive horizontal layers, some of which were clearly visible. Significant changes were noticed as these soils were originated from relatively unconsolidated parent material. Pedons 1, 2, 4, 5 and 6 were developed from granite-gneiss parent material while pedon 7 was developed from alluvium. As per the outlines of Simonson (1959), in the present study the addition of organic matter was observed due to accumulation of organic matter and humus on the surface soils which was indicated by the fact that surface soils were darker than sub-surface soils in all the pedons of the study area. Higher organic matter in the surface soils was due to addition of organic matter through leaf fall, stubbles, roots and organic manures restricting to the surface soils only. Further, the organic carbon was leached to lower layers along with percolating water leading to its loss from the surface soils (Leelavathi *et al*. 2010).

In soil formation, next process was translocation of material from one point to another within the soil. In this category the fundamental pedogenic processes such as eluviation and illuviation had played a significant role. The development of B horizons in the pedons 2, 5 and 6 was a result of illuviation and eluviation. Due to these processes the cambic horizon was formed. However, processes such as eluviation and illuviation were not operated in the pedons 1, 3,4 and 7 as there is no development in diagnostic sub- surface horizons.

Transformation of minerals and organic substances indicated that colour and structure get transformed in the sub-soil leading to the development of cambic horizon (Bw) in pedons 2, 5, and 6. The study area pertains to semi-arid climate with high summer temperatures, and monsoonic type. Natural vegetation was annuals and short grasses. Further, the topography of the study area varied from very gently sloping to nearly level plains. The interplay of climate, topography and vegetation acting on parent material over a period of time resulted in the development of different soils *viz.*, Entisols and Inceptisols in coastal are of Chillakur mandal of SPSR Nellore district of Andhra Pradesh.

Soil classification

Based on morphological characteristics and properties of the typifying pedons, the soils were classified upto sub-group level (Soil Survey Staff 2014). These soils were classified into Entisols and Inceptisols. Pedons 1, 3, 4 and 7 which do not have any diagnostic horizon were classified as Entisols. Pedons 2, 5 and 6 which have cambic (Bw) sub- surface diagnostic horizon were classified under Inceptisols.

Pedons 1, 3 and 4 were placed in Typic Ustorthent at sub-group level were classified under Orthents at sub-order level due to regular decrease in the organic carbon from 25 cm to lithic contact and Ustorthents at great group level due to the presence of ustic soil moisture regime. As these pedons did not show any inter-gradation with any other taxa or any extra-gradation from the central concept, therefore, they are logically classified as Typic Ustorthents at sub-group level.

Pedon 7 was classified under Psamment at sub- order level because of sandy texture. This is kept under Ustipsamment at great group level due to the presence of ustic soil moisture regime. Further, it was classified as Typic Ustipsamment at sub-group level as it showed typical characteristics of Ustipsamment.

Pedons 2, 5 and 6 were grouped under Ustepts at sub-order level due to ustic soil moisture regime and Haplustepts at great group level because these pedons did not have either duripan or calcic horizon and base saturation was more than 60% at a depth between 0.25 to 0.75 m from the surface. Further, they did not have lithic contact within 50 cm from the soil surface. Hence, pedons 2, 5 and 6 were logically classified as Typic Haplustept at sub-group level.

Nutrient status and soil fertility

Macronutrients: Soil fertility exhibits the status of different soils with regard to the amount and availability of nutrients essential for plant growth. The available N varied from 59 to 439 kg ha^{-1}, throughout the depth. However, it was found to be maximum in surface horizons and decreased regularly with depth, which is due to decreasing trend of organic carbon with depth and also cultivation of crops are mainly confined to the surface horizon (rhizosphere) only and at regular interval the depleted nitrogen content is supplemented by the external addition of fertilizers during crop cultivation.

The available P varied between 8 and 30 kg ha^{-1} in the pedons of different revenue villages in this mandal. However, the highest available P was observed in the surface horizons and decreased with depth. It might be due to the confinement of crop cultivation to the rhizosphere and supplementing the depleted P by external sources *i.e.* fertilizers and presence of free iron oxide and exchangeable Al^{3+} in smaller amounts (Thangasamy *et al.* 2005). The lower phosphorus content in sub- surface horizons as compared to surface horizon was due to the fixation of released P by clay minerals and oxides of iron and aluminum.

Available K of soils ranged from 78 to 327 kg ha^{-1}. The highest available K content was observed in the surface horizons and showed more or less a decreasing trend with depth. This might be attributed to more intense weathering, release of liable K from organic residues, application of K fertilizers and upward translocation of K from lower depths along with capillary raise of ground water. The available S in soils varied from 15 to 40 mg kg^{-1}. Available S is more in surface horizons than sub-surface horizons which is due to higher amount of organic matter in surface layers than in deeper layers.

Micronutrients: The DTPA extractable Zn ranged from 0.28 to 0.57 mg kg^{-1} soil. Vertical distribution of Zn exhibited little variation with depth. Considering 0.6 mg kg^{-1} as critical level (Lindsay and Norvell 1978), these soils were deficient in available Zn. The low available Zn was possibly due to high soil pH values which might be resulted in the formation of insoluble compounds of Zn or insoluble calcium zincate (Prasad *et al.* 2009).

All the pedons were found to be sufficient in available Cu (0.21 to 1.74 mg kg^{-1}) as all the values were well above the critical limit of 0.20 mg kg^{-1} soil as suggested by Lindsay and Norvell (1978). The DTPA extractable Fe content varied from 1.94 to 14.17 mg kg^{-1} soil. According to critical limit of 4.5 mg kg^{-1} of Lindsay and Norvell (1978), all the soils were sufficient in available Fe except pedon 7 wherein the soils were deficient in available Fe. The distribution of available Fe in all the pedons did not shows a definite pattern. Surface horizons had higher concentration of DTPA-extractable Fe than sub-surface horizons due to higher organic carbon in surface horizons. Available Mn varied from 1.10 to 6.24 mg kg^{-1} soil. According to critical limit of 1.0 $mgkg^{-1}$ of Lindsay and Norvell (1978), the soils were sufficient in available manganese and almost decreased with depth which might be due to higher biological activity and chelating of organic compounds released during the decomposition of organic matter left after harvesting of crop. The above fact is confirmed by the positive and significant (r=0.824) correlation between organic carbon and available Mn.

Land evaluation

Land capability classification

Based on the criteria given in the land capability classification the coastal soils of Chillakur mandal have been classified into two land capability classes and four land capability sub-classes for better management of lands (Table 1). Pedon 2 was rated as IIIws. Pedons 5 and 6 were placed in IIIs, pedons 1, 3 and 4 were placed under IVse and pedon 7 was classified as IVs. The detailed description of land capability classes with potentials, limitations and suggested land use is given in table 5. By adopting suggesting land use in the respective areas sustained crop production can be achieved as it helps in the conservation of soil and water besides the improvement of physical properties of soils.

Soil –site suitability for growing crops

Pedons 1, 3 and 4, which were classified under Typic Ustorthents were marginally suitable (S3) for rice, groundnut, sesame and sunflower crops. The major limiting factors for growth of rice, groundnut, sesame and sunflower in these soils were wetness, texture, shallow depth and low organic carbon. Similarly, Kumar and Naidu (2012) reported Typic Ustorthents were marginally suitable for growing rice crop in Vadamalapeta mandal of Chittoor district of Andhra Pradesh

Pedons 2, 5 and 6 were grouped under Typic Haplustepts. All these pedons were marginally suitable (S3) for crops like rice, groundnut, sesame and sunflower. Soil fertility characteristics *viz*., pH and organic carbon and physical soil characteristics like texture and drainage were the limitations. Organic carbon and pH were major limitations for all the four crops whereas soil texture was a limitation for rice crop. However, heavy texture and improper drainage were found to be important soil related constraints in growing these crops. Leelavathi *et al*. (2010) reported that Typic Haplustepts were marginally suitable (S3) for growing paddy crop in Yerpedu mandal of Chittoor district in Andhra Pradesh.

Pedon 7 was grouped under Typic Ustipsamment, was marginally suitable (S3) for growing groundnut, sesame and sunflower crops and temporarily not suitable (N1) for rice crop. This soil had limitations of excessively drained, physical characteristics like sandy texture and fertility characteristics like low sum of basic cations (low fertility) and low organic carbon. These findings were in good agreement with results of Sekhar *et al*. (2014) who stated that Typic Ustipsamment was temporarily not suitable (N1) for growing rice crop in soils of central and eastern parts in Prakasam district of Andhra Pradesh.

Conclusions

The study of morphological properties and determination of physical and chemical properties of soil revealed that the coastal soils of Chillakur mandal were slightly acidic to moderately alkaline in reaction, non-saline, low to medium in organic carbon and low in $CaCO_3$ status. CEC was low to medium and exchange complex was dominated by Ca^{+2} followed by Mg^{+2}, Na^{+} and K^{+}. The soils were low to medium in available nitrogen and phosphorus, low to high in available potassium and high in available sulphur. However, soils were deficient in available zinc and sufficient in available copper, manganese and iron (except pedon 7). The coastal soils of Chillakur mandal were classified as Typic Ustorthents, Typic Ustipsamment and Typic Haplustepts. Land capability classes were fixed and suitable land use plan was also suggested for sustaining yields of the crops in Chillakur mandal .Furthermore, the soil-site suitability for growing different crops like rice, groundnut, sunflower and sesame revealed that all the pedons (1, 2, 3, 4, 5, 6 and 7) exhibited low organic carbon as severe limitation. Shallow depth was a major limitation for pedons 1, 3 and 4 whereas texture was a major limitation for growing rice crop in pedon 7. High pH is a major limitation in pedon 2. Organic carbon status in these soils can be improved by the application of farm yard manure, green manuring and inclusion of legumes in rotation and pH can be controlled by application of organic manures and sulphur. Soil texture can be improved by mixing with tank silt year after year. By correcting the above limitations sustainable yields can be achieved in rice, groundnut, sunflower and sesame crops. Hence, green manuring, addition of crop residues and organic manures in combination with chemical fertilizers in balanced form not only helps to achieve sustainable yields of crops but also maintains the soil health without undergoing deterioration of coastal soils of Andhra Pradesh.

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Table 1. Interpretation of coastal soils of Chillakur mandal of SPSR Nellore district of Andhra Pradesh

Pedon No.	Land capability class with limitations	Description	Major limitations	Suggested land use
1.	IVse	Fairly good cultivable land for sustainable agriculture	Shallow depth, gentle slope, moderate erosion, poor nutrient status, moderate run-off and moderate water holding capacity	Double cropping including legumes in rotation, addition of fertilizers and manures and adopting moderate soil conservation measures
2.	IIIws	Moderately good cultivable land for sustainable agriculture	Poor drainage, poor permeability, alkaline soil reaction and tillage problems.	Cultivation with precaution against permanent damage, moderate soil conservation measures, growing of leguminous crops in rotation and application of organic manures.
3.	IVse	Fairly good cultivable land for sustainable agriculture	Low organic matter content, shallow depth, gentle slope, moderate erosion and moderate run-off,	Double cropping including legumes in rotation with special soil and water management practices and addition of organic manures.
4.	IVse	Fairly good cultivable land for sustainable agriculture	Shallow depth, gentle slope, moderate erosion, moderate run-off, poor nutrient status and low organic matter content.	moderate soil conservation measures, very careful soil and water management practices could be followed and suitable for fruit crops like mango
5.	IIIs	Moderately good cultivable land for sustainable agriculture	Poor fertility status and low organic matter content.	Moderate soil conservation measures, application of organic manures and rice, groundnut and sesame could be grown.
6.	IIIs	Moderately good cultivable land for sustainable agriculture	Poor nutrient status, moderate water holding capacity, low organic matter content and tillage problems.	Special soil-conserving cropping systems, crop rotation that includes grasses and legumes, growing of green manure crops, stubble mulching and suitable for crops like groundnut, sunflower and sesame.
7.	IVs	Fairly good cultivable land for sustainable agriculture	Sandy texture, low water holding capacity, poor fertility status, low organic matter content and excessively drained.	Addition of tank silt (pond mud) is recommended and very careful soil and water management practices could be followed and groundnut and plantation crops like cashew could be grown.

Integrated Nutrient Management Research in ANGRAU- In a Nutshell

Vijay Sankar Babu M, Usha Rani T, Madhuvani P and Sahadeva Reddy B

Acharya NG Ranga Agricultural University, Guntur-522 034, Andhra Pradesh, India

Can agriculture provide for the food needs of a world population projected to exceed 7.5 billion by the year 2030. Concern is growing that it may not. Furthermore, new technologies such as genetically engineered, yield-increasing plants are not expected to be major factors in food production increases in developing countries during the next two decades (Hazell 1995; Peng, Khush, and Cassman 1994). Consequently, keeping pace with population growth and increasing land scarcity will be more difficult than in the recent past. In developed countries, for example, over application of inorganic and organic fertilizer 1 has led to environmental contamination of water supplies and soils (Conway and Pretty 1991; Bumb and Baanante 1996; NRC 1989). In developing countries, harsh climatic conditions, population pressure, landconstraints, and the decline of traditional soil management practices have often reduced soil fertility (Stoorvogel and Smaling 1990; Tandon 1998; Henao and Baanante 1999; Bumb and Baanante 1996). Because agriculture is a soil-based industry that extracts nutrients from the soil, effective and efficient approaches to slowing that removal and returning nutrients to the soil will be required in order to maintain and increase crop productivity and sustain agriculture for the long term. The overall strategy for increasing crop yields and sustaining them at a high level must include an integrated approach to the management of soil nutrients, along with other measures. An integrated approach recognizes that soils are the storehouse of most of the plant nutrients essential for plant growth and that the way in which nutrients are managed will have a major impact on plant growth, soil fertility, and agricultural sustainability. Farmers, researchers, institutions, and government all have an important role to play in sustaining agricultural productivity.

With the change-over of the cropping pattern and the adoption of high- production technology, modern farming achieved a breakthrough in the age-old yield barrier giving new dimensions to agricultural production. The nutrient input requirements have also increased several-fold with the introduction of high-yielding and nutrient-responsive crops varieties resulting in a rapid turnover impact on soil and crop environments than ever conceived before, it becomes, therefore imperative to examine the sustainability of modern intensive farming on a long-term basis. Realising the importance, the Indian Council of Agriculture Research sponsored the All India Co-ordinated Research Project on Long-term Fertilizer Experiments during the fourth plan period (September 1970) in selected centres.

The information on effects of long-term application of fertilizer and manures in different crops grown on various soil types in Andhra Pradesh is very meagre. Hence, the research on Long-term experiments are planned at ANGRAU in three major crops at four locations as mentioned below with main objective to know the impact of application of fertilizers and manures on long-term basis on various soil properties as well as on crop productivity.

1. Cotton: RARS, Lam (in 1991, 28 years)
2. Groundnut (Rainfed): ARS, Anantapuramu (in 1985, 34 years)
3. Paddy-paddy: RARS, Maruteru (in 1989, 30 years)

1. Long-Term Soil Fertility Management in Black Cotton Soils of Krishna Zone on Productivity of Rainfed Cotton

Cotton, the 'white gold' and 'king of fibre crops' enjoys a pre-eminent status among all the cash crops in the country and elsewhere by providing cotton, the principal raw material, nearly 75 per cent of raw material needs of textile industry. In Andhra Pradesh, cotton is a crop of great economic value, playing a significant role in the socioeconomic status of the farmers. It occupies an area of about 5.51 lakh ha with an annual production of 20 lakh bales and productivity of 617 kg lint ha^{-1} (Cotton Advisory Board, 2018-19). In Andhra Pradesh the crop is predominantly cultivated under rain fed ecosystem. Majority of the cotton growing soils include black cotton soils (Vertisols) in coastal Andhra , parts of Rayalaseema and light soils in rest of the cotton growing regions of Andhra Pradesh for the past few decades. A permanent long-term experiment on cotton is being carried out at RARS, Lam, Guntur since 1991during *kharif* in cotton on Vertisols with nine treatments.

T_1 : Control (No fertilizer or manure)

T_2: 50% recommended dose of NPK

T_3 : 100% recommended dose of NPK

T_4 : 150% recommended dose of NPK

T_5 : 100% recommended dose of NP

T_6 : 100% recommended dose of N

T_7 : T_3 +FYM @ 10 t ha^{-1}

T_8 : T_3 + $ZnSO_4$ @ 50 kg ha^{-1}

T_9 : T_3 + $MgSO_4$ @ 50 kg ha^{-1}

T_{10} : 200% recommended dose of NPK

T_{11} : T_3 + Gypsum @ 0.5 t ha^{-1}

Seed cotton yield

The highest productivity of seed cotton yield (2265 kg ha^{-1}) was recorded with the application of farmyard manure @ 10 t ha^{-1} +100% NPK and the lowest was recorded in control. The treatment which received integrated nutrient application was significantly higher in productivity over control. The average seed cotton yield of 28 years indicated that application of 150 and 200 per cent NPK did not yield higher productivity. Non-application of potassium (T_5) and phosphorus and potassium (T_6) through mineral fertilizer showed reduction in the total productivity over 100 per cent NPK (T_2). The seed cotton yields were lower in the initial years (1991-2001) and higher in the later years in all the treatments might be due to cultivation of Bt hybrids.

Soil properties

Among the treatments the lowest bulk density was recorded in treatment which received integrated nutrient application in all the years and the treatments which received only fertilizer and non application of fertilizer recorded higher bulk density values. Application of fertilizers and FYM on long-term basis and continuous cropping for 28 years decreased soil pH. In all the treatments the average soil pH was lower between 2016 and 2018 when compared to the previous years. It was observed that in every five years mean, the treatment which received FYM and gypsum showed decreased (negative) soil reaction over the control and 100% NPK during entire period of experimentation.

Application of FYM along with 100% NPK recorded the highest organic carbon status when compared to the treatments which received zinc, magnesium and gypsum in addition to 100% NPK. Application of FYM is instrumental in almost doubling the organic carbon status. Among the treatments, highest average nitrogen content was recorded in integrated nutrient application followed by the treatments which received high doses of NPK fertilization. The application of farmyard manure @10 t ha^{-1} + 100% NPK increased the availability of phosphorus by 41.3, 16 and 7.3 per cent compared to 100 per cent NPK, supra optimal dose of fertilizers (150 and 200% NPK), respectively without any organic addition. The maximum build-up of available phosphorus was observed under NPK+ farmyard manure. Among the treatments maximum build-up was observed under NPK+ farmyard manure and the minimum in control. The treatments which received higher doses of NPK fertilization maintained higher status of available K in soils. The available sulphur status in integrated nutrient application of nutrients and in the treatment which received sulphur in the form of zinc sulphate, magnesium sulphate and gypsum. Maximum improvement was recorded in treatment which received 100% NPK and $ZnSO_4$@ 50 kg ha^{-1} followed by treatment with integrated nutrient application of nutrients.

2. Long-Term Soil Fertility Management in Low Land Alluvial soils of Godavari Delta Under Rice-Rice Cropping System

Rice (*Oryza sativa* L.) is the staple food for more than 50 per cent of the world's population and the world rice production must increase by 1.15 per cent annually to meet the demand of ever increasing population. The experiment was conducted at RARS, Maruteru from 1989 to 2018.

T_1	Control	T_{10}	50% NPK + 50% FYM – N
T_2	100% N	T_{11}	50% NPK + 25% GM –N + 25% FYM – N
T_3	100% NP	T_{12}	FYM @ 10 tha^{-1}
T_4	100% NPK + Zn +S	T_{13}	100% PK
T_5	100% NPK (-) Zn	T_{14}	100%NPK + Zn +S + FYM @ 5 tha^{-1}
$T_{6:}$	100% NPK (-) S	T_{15}	STCR (114-78-41 $kgha^{-1}$)
T_7	100% N + 50% P + 50%K	T_{16}	50% NP*K* + *Azospirillum*
T_8	50% NPK	T_{17}	FYM @ 10 tha^{-1}+ split application of vermicompost
T_9	50% NPK + 50% GM – N		

Grain Yield: Lowest yields were with the control while the treatment where 100% NPK + Zn + S were applied, recorded the highest increase in yield (over control) by 15% during *kharif* and 44% during r*abi*. The maximum reduction in yield was with the application of 50% NPK and 100% PK up to 2008-2009.

Straw Yield : Lowest yields were with the control while the treatment where 100% NPK + Zn + S applied recorded highest yields by 12.5% during *kharif* and 33 per cent during r*abi* season. Application of 100% NPK + Zn + S + FYM @ 5t ha^{-1} (T_{14}) recorded highest grain yields over control by 24% during *kharif* and 25% during *rabi* season.

Soil properties

Application of fertilizers and manures on long-term basis and continuous cropping for 30 years indicated that the soil pH was lowered in all the treatments when compared to control. The soil pH in

T_{14} treatment was the lowest when compared to all other treatments with a fall by 3.12 per cent when compared to control. Application of fertilizers and manure on long-term basis and continuous cropping for 30 years increased soil organic carbon. The per cent increase over control was maximum with T_{12} treatment where FYM @ 10 t ha^{-1} alone was applied followed by application of 100% NPK + Zn + S along with FYM @10 t ha^{-1} during *kharif* and *rabi.* The increase in organic carbon might be due to incorporation of paddy stubbles in addition to FYM and green manure. Application of fertilizers and manures on long-term basis and continuous cropping for 30 years declined organic carbon percentage with the application of only 100% NPK indicated that the organic carbon percentage showed increase where FYM was applied in T_{14}, T_{12} and T_{11}.

The available nitrogen declined in all the treatments except T_{11} and T_{14} where FYM was applied. Application of 100 per cent NPK along with FYM @ 5 t ha^{-1} plot recordedhighest level of nitrogen in comparison to all the other treatments and T_{11} and T_{12} also had higher mean available nitrogen when compared to all other treatments. The treatment where INM was practiced (T_{11}, T_{12}, T_{10} and T_{14}) showed positive values *i.e.,* soil available N was high compared to 100% NPK without any organics. The available phosphorus build up was observed from 1989 to 2019 and the build up was more with T_4 treatment where 100% NPK + Zn + S was applied followed by 100% NPK + Zn + S along with 5 t ha^{-1} .The per cent increase over control was maximum with T_4 and T_{10} followed by T_{14} during *kharif* and also in *rabi* and the build up of phosphorus was maximum with the conjunctive use of organics along with inorganic fertilizers. Highest level of accumulation was observed in T_{12} treatment when compared to control followed by T_4. When compared to the initial levels at the start of the experiment, T_{12} treatment had highest build up of soil available potassium. The build up of potassium was maximum in T_{12} where FYM alone was applied followed by 100% NPK which was on par with conjunctive use of organic manure with inorganic fertilizers.

3. Long-Term Soil Fertility Management in Red Sandy Loam Soils (*Alfisols*) of Scarce Rainfall Zone on Productivity of Rainfed Groundnut

Scarce rainfall zone comprises Ananthapuramu and Kurnool districts of Andhra Pradesh where average annual rainfall is very low coupled with low soil moisture storage capacity thus resulting in short crop growth period. In Ananthapuramu district, groundnut is being cultivated in 4,23 L ha mainly under rainfed agriculture realizing the importance of soil and water conservation, Acharya N.G. Ranga Agricultural University has started “Soil Conservation Research Centre” during the year 1964 at Rekulakunta village, Ananthapuramu district. Rekulakunta village is situated at 12 km away from Ananthapuramu 14° - 41’ N latitude, 77° - 40’ E longitude at an altitude of 350 m above MSL. Later in 1971, Indian Council of Agricultural Research has sanctioned All India Coordinated Research Project for Dryland Agriculture (AICRPDA) to carry out multi-disciplinary research work on all aspects of dryland farming to cater the needs of dryland farmers in the red soil areas of Rayalaseema region of Andhra Pradesh.

A long-term experiment was initiated in *kharif* 1985 at the Agricultural Research Station, Ananthapuramu, Andhra Pradesh, India under the All-India Coordinated Research Project for Dryland Agriculture (AICRPDA) to study the long-term effect of organic manures, fertilizers and their interaction on soil health and crop productivity. The study was conducted in monocropping system of groundnut. The soils of experimental site is classified as *Rhodostalfs* (Voyalpadu series).

Table 1. Average seed cotton yield (kg ha^{-1}) of cotton, per cent change over control and 100 per cent NPK with long-term fertilization at Lam

Treatment particulars	1991-95	Control	100% NPK	1996-2000	Control	100% NPK	2001-05	Control	100% NPK	2006-10	Control	100% NPK
T_1 : Control	996	0.00	-31	667	0.00	-33	1173	0.00	-29	1808	0.00	-28
T_2 : 50% NPK	1213	21.79	-15.3	846	26.84	-15	1402	19.52	-15	2124	17.48	-15.5
T_3 : 100% NPK	1432	43.78	-	996	49.33	-	1656	41.18	-	2513	38.99	-
T_4 : 150% NPK	1571	57.73	9.7	1048	57.12	5	1858	58.40	12	2602	43.92	3.5
T_5 : 100% NP	1369	37.45	-4.4	1013	51.87	1.7	1587	35.29	-4.2	2271	25.61	-9.6
T_6 : 100% N	1429	43.47	-0.21	923	38.38	-7.3	1637	39.56	-1.1	2483	37.33	-1.19
T_7 : 100% NPK + FYM 10 t ha^{-1}	1601	60.74	11.8	1098	64.62	10	1802	53.62	8.8	2761	52.71	9.87
T_8 : 100% NPK + 50 kg $ZnSO_4$ ha^{-1}	1406	41.16	-1.8	997	49.48	0.1	1797	53.20	8.5	2358	30.42	-6.2
T_9 : 100% NPK + 50 kg $MgSO_4$ ha^{-1}	1358	36.35	-5.17	992	48.73	-0.4	1652	40.84	-0.24	2487	37.56	-1.03
T_{10} : 200% NPK*	821	-17.57	-43	1028	54.12	3.2	1562	33.16	-5.7	2439	34.90	-2.9
T_{11} : 100% NPK + Gypsum @ 0.5 t ha^{-1}*	814	-18.27	-43	898	34.63	-9.8	1438	22.59	-13	2508	38.60	-0.2

Treatment particulars	2011-15	Control	100% NPK	2016-18	Control	100% NPK	28 years average	Control	100% NPK
T_1 : Control	1433	0.00	-31.5	2119	0.00	-25.4	1366	0.00	-28.9
T_2 : 50% NPK	1764	23.10	-15.7	2532	19.49	-10.9	1647	20.57	-14.3
T_3 : 100% NPK	2093	46.06	-	2842	34.12	-	1922	40.70	-
T_4 : 150% NPK	2418	68.74	15.5	3263	53.99	14.8	2127	55.71	10.6
T_5 : 100% NP	1952	36.22	-6.7	2660	25.53	-6.4	1809	32.43	-5.9
T_6 : 100% N	1884	31.47	-9.99	2867	35.30	0.88	1871	36.97	-2.6
T_7 : 100% NPK + FYM 10 t ha^{-1}	2538	77.11	21.3	3790	78.86	33.4	2265	65.81	17.8

Treatments : T_1 : Control (No fertilizers and manures)

T_2: 20-40-40 N, P_2O_5, K_2O kg ha^{-1}

T_3: 10-20-20 N, P_2O_5, K_2O kg ha^{-1} (HRFD)

T_4 : Groundnut Shells @ 4 t ha^{-1}

T_5: FYM @ 4 t ha^{-1}

T_6 : T_3 (HRFD) + T_4

T_7: T_3 (HRFD) + T_5

T_8 : T_2 + $ZnSO_4$ @ 50 kg ha^{-1} (once in 3 years)

T_9 : FYM @ 5t ha^{-1}

T_{10} : T_2 + T_4

Pod yields: The lowest groundnut pod yield was recorded in control treatment (164 kg ha^{-1}) in 2014, while the maximum was in INM treatment which received HRFD + FYM @ 4 t ha^{-1} (2202 kg ha^{-1}) in 2017. Significantly higher pod yield was observed with FYM @ 4 t ha^{-1} along with HRFD (10-20-20 N - P_2O_5 - K_2O kg ha^{-1}) compared to absolute control and application of only NPK *i.e.*, Full Recommended Fertilizer Dose (RFD), but it was on par with INM treatment *i.e.*, FYM @ 4 t ha^{-1} along with HRFD (10-20-20 N P_2O_5 K_2O kg ha^{-1})

Soil properties

All the treatments showed that the soil pH was altered when compared to the control plot. The soil pH in HRFD + Groundnut shells @4 t ha^{-1} applied treatment was the lowest when compared to all other treatments with a fall by 2.5% when compared to the control. The treatments where only FYM @ 5t ha^{-1} (4.3%) and HRFD + FYM @ 4 t ha^{-1} (3.2%) applied were slightly above the control. Organic carbon of soils increased in all treatments when compared to control over 34 years of application of fertilizers and manures. HRFD + FYM @ 4 t ha^{-1} treatment had the highest organic carbon levels of 60.46% and 47.93% when compared to control and Full Recommended Fertilizer Dose. Application of FYM is instrumental in enhancing the organic carbon status. Highest level of accumulation was observed in Full Recommended Fertilizer Dose (T_2) treatment when compared to control followed by T_7 (193%) and T_6 (127%). Results indicated that available potassium levels declined in all the treatments in depleted studies. The depletion was more with T_6 when compared to all other treatments.

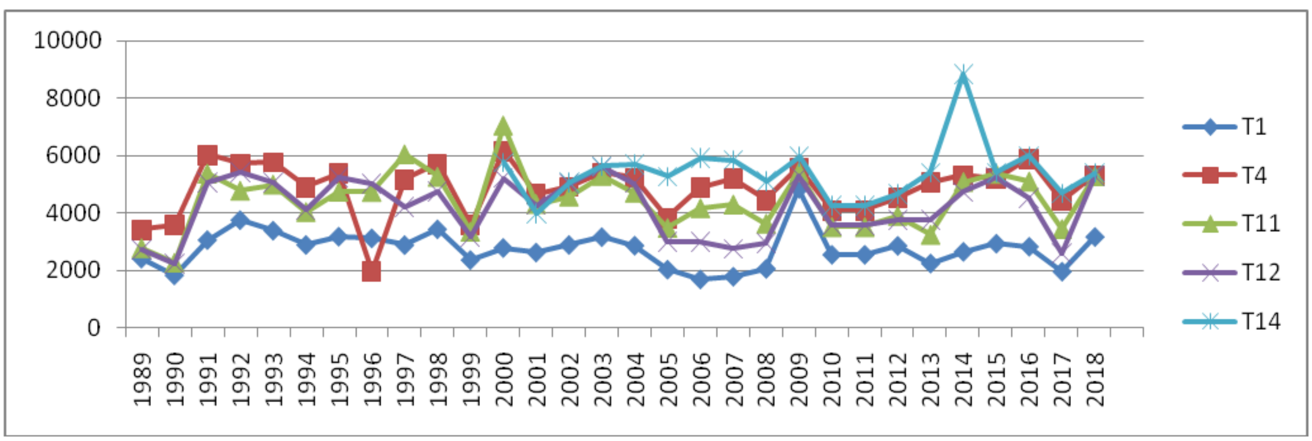

Fig. 2. Changes in Grain yield (kg ha^{-1}) during *kharif* from 1989 – 2018 at Maruteru

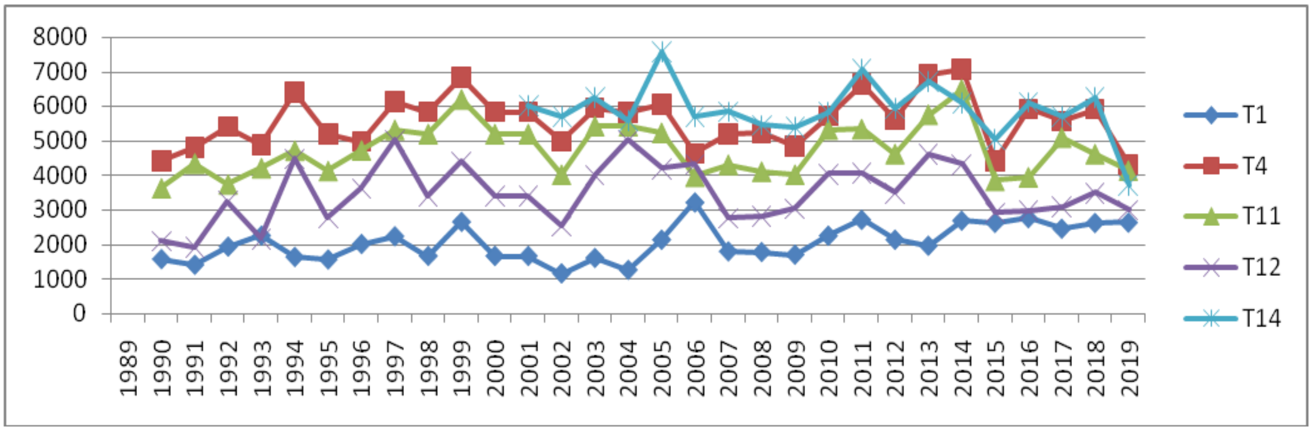

Fig. 3. Changes in Grain yield (kg ha^{-1}) during *rabi* from 1989 – 2018 at Maruteru

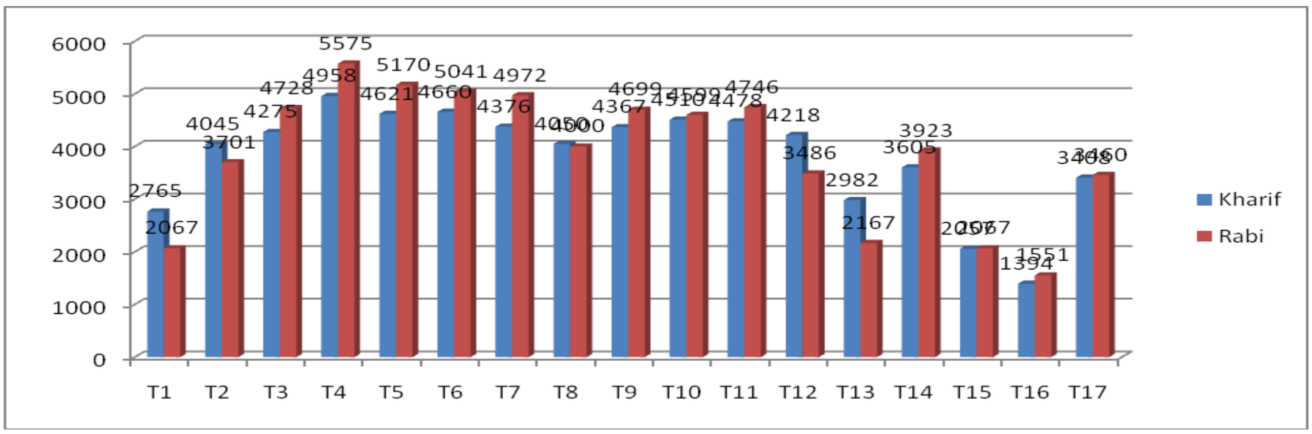

Fig. 4. Changes in grain yield (kg ha^{-1}) during *kharif* and *rabi* seasons from 1989 to 2018 (mean values) at Maruteru

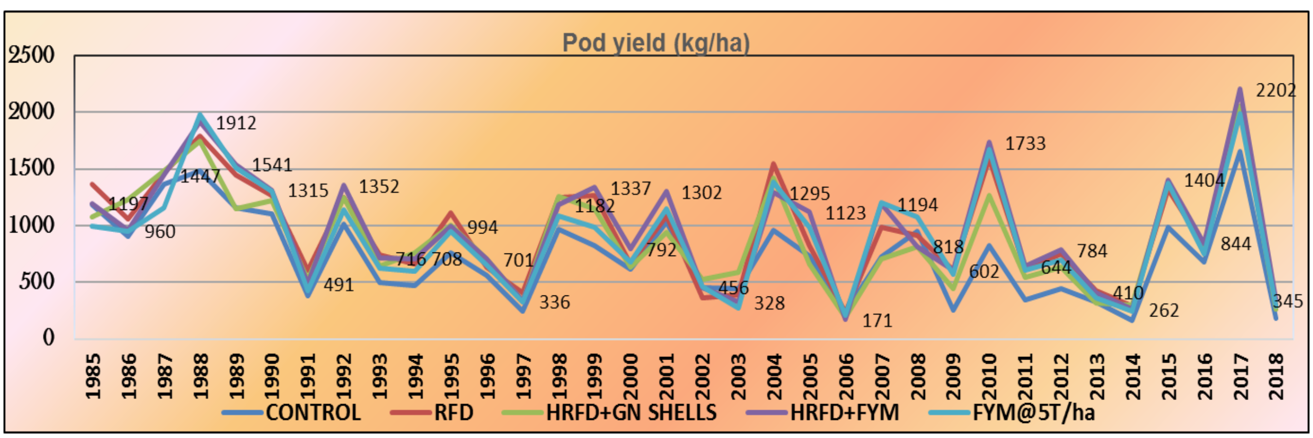

Fig. 4. Effect of long-term Integrated Nutrient Management on groundnut pod yield (kg ha^{-1}) since 1985 (34 yrs) at Anantapur

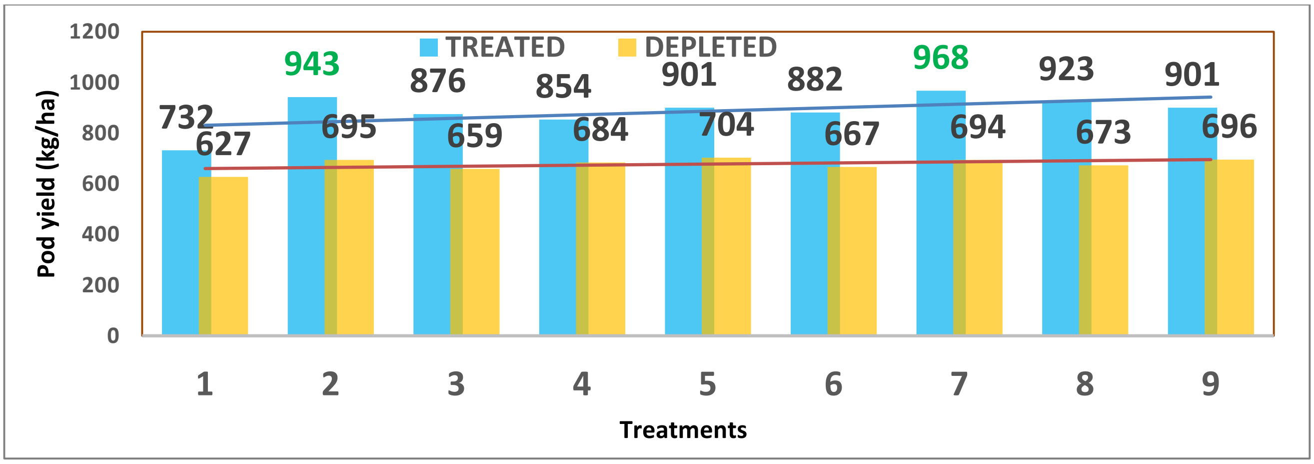

Fig. 5. Effect of long-term Integrated Nutrient Management on groundnut pod yield (kg ha^{-1}) since 1985 (34 yrs) and (26 yrs) at Anantapur

Groundnut responds positively in terms of SYI to the organic sources in long run compared to negative trend with inorganic fertilizers. Application of FYM @ 4 t ha^{-1} + 50% NPK recorded higher SYI (0.234) followed by 100% NPK (0.223) compared to absolute control (0.127). This clearly indicates that continuous use of only fertilizers is not sustainable, as it will effect soil fertility and soil properties. When it was used along with FYM, the productivity was maintained at higher sustainable level.

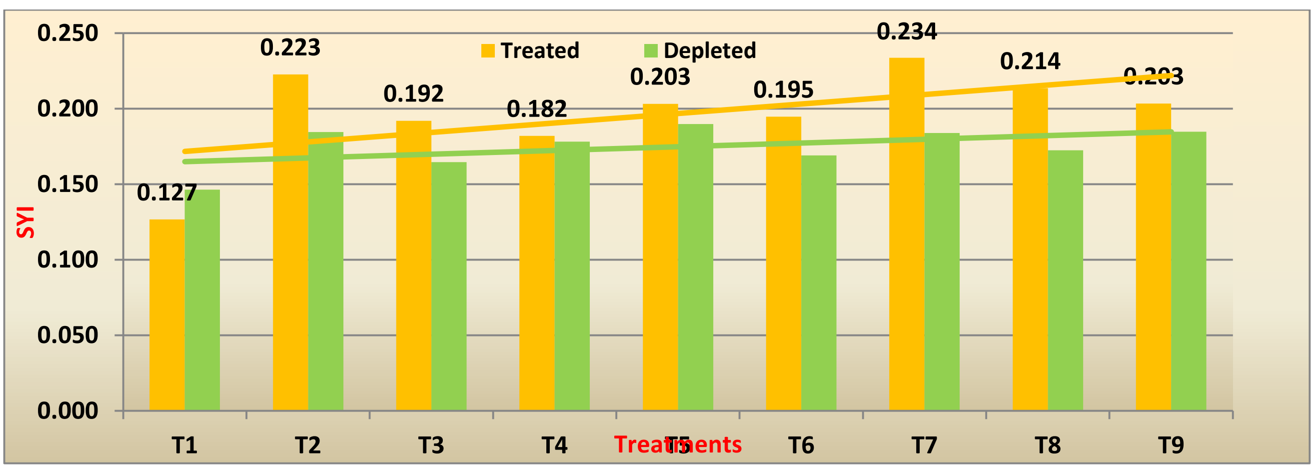

Fig. 6. Effect of long-term Integrated Nutrient Management on Sustainability Yield Index (SYI) at Anantapur

Conclusions

The research carried out in ANGRAU on Long-term fertilizer applications on paddy, cotton and groundnut crops indicated that:

In cotton, long-term application of farmyard manure at 10 tha^{-1} in combination with 100% recommended NPK to cotton significantly improved the soil physical, physico-chemical and chemical properties as well as productivity. Significant relationship between rainfall and cotton seed yield was observed over the years. The results of LTFE on cotton indicate that recommended Nitrogen dose must be applied every year to maintain soil fertility and obtaining promising yields of the variety and build up of phosphorus and potassium status over initial even in control treatment with mono cropping.

In rice-rice cropping system of Godavari delta system (Maruteru), there was a buildup in soil OC where conjunctive use of fertilisers and organic manures were applied while it was depleted in available K and of N. In general, INM treatments were found to maintain P fertility partially at Maruteru. Exclusion of sulphur from the fertilizer schedule for the last 10 years in these heavy fertile Godavari alluvial soils has not affected either the grain yield or available sulphur content in soils possibly due to recycling of substantial crop residues through stubbles, fertility value of sediment deposited by Godavari water during season due to heavy texture of the soils.The results of LTFE on rice- rice system suggest that the application of organics over and above RDF could improve crop and soil productivity while there is scope for economizing fertilizer nutrients through partial substitution with green manures and FYM.

At Anantapuramu, the results of LTFE on groundnut show that the treatment with half the recommended dose of fertilizer (10:20:20 kg N, P_2O_5, K_2O) along with FYM @ 4 t/ha recorded higher Soil Organic carbon stocks (13.42 Mg/ha) and Microbial biomass carbon (1035 µg/g) at surface soil depth. Application of full recommended fertilizer dose (20 N, 40 P_2O_5 and 40 kg/ha K_2O) applied when the soil test values for NPK were low and half the recommended fertilizer dose (20 N, 20 P_2O_5 and 20 K_2O kg/ha) is sufficient when P and K are medium in range. However, application of P and K are not required when the soil test values are high. The initial available phosphorous content (20 kg/ha) of LTFE at Anantapuramu increased to 95 kg/ha in treatments received with full rec. fertilizer dose as inorganics alone compared to other treatments, whereas available potassium content increased over initial values in treatments received with organics or organics in combination with inorganics, over control.

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Biochar : An Amendment for Coastal Salt Affected Soils

Sailaja V[1], Sai Manjeera K[2], Madhuvani P[3] and Asha Jyothi B[4]

1 Principal Scientist (Soil Science), RARS, Lam
2 Ph.D Scholar (Soil Science), S.V. Agricultural College, Tirupathi
3 Senior Scientist (Soil Science), RARS, Lam
4 Senior Scientist (Soil Science), RARS, Lam
Acharya N.G. Ranga Agricultural University

Salt-affected soils (SAS) include saline, sodic, and saline-sodic soils and many sub-categories depending on the type of salt. Saline soils contain an excessive amount of soluble salts that impair soil health (or soil quality), which has been defined as the capacity of a soil to sustain plant and animal productivity and maintain or enhance water and air quality, and support human health and habitation over a human time scale (https://www.fao.org/3/cb7247en/cb7247en.pdf).

The GSAS map represents the spatial distribution of salt affected soils with EC> 2 dS m^{-1}, ESP > 15% and pH>8.2 at two depth intervals (0-30 and 30-100 cm). With the current information from 118 countries covering 85% of global land area, it shows that more than 424 m ha of top soil (0-30 cm) and 833 m ha of subsoil (30-100 cm) are salt affected. Data shows that about 85% of salt affected topsoils are saline, 10% are sodic and 5% are saline-sodic; 62% of salt affected subsoils are saline, 24% are sodic and 14% are saline-sodic. Further, 3% of global topsoils and more than 6% global subsoils are affected by salinity or sodicity. Additionally, the salt-affected area is increasing at a rate of 10% yearly because of high evaporation, low rainfall, inadequate irrigation, and other irrational anthropogenic activity (Liu *et al*., 2017). By 2050, the salinized area will exceed 50% of global arable land (Mao Kang*et al*., 2016). On a global scale, salinization is causing the loss of arable land area of about 2000 ha per day, contributing 1 to 2% agricultural soil losses every year worldwide (Zaman *et al*., 2018). In order to meet the challenges of global food security, it is imperative to bring barren salt-affected soils under cultivation (Biswas and Biswas, 2014). Salt-affected soils can be used successfully for crop production following measures aimed at removal of soluble salts and/or exchangeable Na (reclamation of salt-affected soils) or minimizing the adverse impacts of salts on plants (management of salt-affected soils).

Various organic and inorganic amendments are used for saline soil remediation. Organic amendments such as compost, poultry manure, sheep manure etc. could be a direct source of Ca and Mg to aid in the removal of Na^+ from the soil exchange complex (Walker and Bernal, 2008). However, repeated applications of organic amendments with a high quantity of decomposable organic substrates at elevated rates is neither economically feasible nor environmentally friendly as they may increase CO_2 emission (Al-Wabel *et al*., 2017).

The addition of biochar to salt affected soil could restore the soil organic carbon, which improves soil quality and enhances the growth of plants or microorganisms (Madhavi *et al*., 2017; Sailaja, 2021). Biochar, known as the porous solid carbonaceous material produced at elevated temperatures ranging from 300°C to 1,000°C under oxygen deficit condition, is gaining considerable attention. Such a process transforms the easily oxidized carbon fractions present in the organic residues into more stable forms that can persist in soils for years which can be considered as a climate change mitigation strategy (Lehman and Joseph, 2009). The use of biochar is being considered as a win-win practice for achieving multiple benefits of sustainable agriculture. Recently, biochar has attracted considerable attention as a soil amendment (Qi *et al*., 2017b), with carbon-residence time varying from tens of years to millennia (Wang *et al*., 2016). Biochar is widely reported to enhance the sorption of nutrients and reduce nutrient leaching from the soil and improves the physical, chemical and biological properties of saline soil. There are still gaps in deciphering the remediation mechanisms of the biochar.

Properties of Biochar

Biochars should be carefully analyzed prior to their utilization. The properties of biochar highly rely on the type of feedstock and the pyrolysis process used (Tasim *et al*., 2019). Cob corn biochar (CCB) has a high an alkaline pH (8.1), carbon content (60.3%) and oxygen (30.4%), while it has a low content of nitrogen (0.7%), phosphorus (0.25%), and potassium (1.7%). In addition, CCB has a high BET surface area (29.6 m^2 g^{-1}) which enhances nutrients' and cations' adsorption on its surface (Mohamed *et al*., 2017). Likewise, the water-holding capacity of dry biochar was 1.67 g g^{-1}. The CCB has alkaline pH and low EC values (Rajkovich *et al*., 2011).

The Fourier transform infrared (FTIR) spectroscopy test showed that the main functional groups of the CCB were detected as the hydroxyl group –OH (3400 cm^{-1}), aromatic C=C (1607 cm^{-1}), COOH (1700 cm^{-1}), phenolic C−OH (1187 and 1260 cm^{-1}), aromatic CH (750, 836, 874, and 3029 cm^{-1}), and aliphatic CH (2862 and 2921 cm^{-1}). These functional groups are particularly important in the retention of nutrients and cations within the soil matrix (Singh *et al*., 2016). Zhang and Luo (2014) investigated the surface functional properties of biochar derived from the leaves of Eucalyptus plant (EBC) and anaerobically digested garden wastes (ADB) through FTIR, Boehm titrations, and scanning electron microscopy. The total amount of functional groups was higher in EBC as compared to that in ADB.

Cotton stalk biochar was found to possess a pH of 8.20, electrical conductivity of 1.28 dS m^{-1}, cation exchange capacity of 49 c mol (p^+) kg^{-1}, total negative charges of 2.60 m mol H^+eq g^{-1}, total acidity of 2.5 me g^{-1} and carboxyl groups to the tune of 0.2 me g^{-1} and a bulk density of 0.6 g/cc (Madhavi *et al*., 2017 and Sailaja, 2021). In the case of biochar derived from woody-materials under the pressure of the atmosphere, the porosity range varies from about 50% at 300°C to 70% at 850°C (Somerville *et al*., 2015). However, hydrophobicity feature is linked to the surface functional groups, although the water holding capacity is reliant on the porosity of biochars' bulk volume (Pimchuai *et al*., 2010). The surface area is closely related to the emission of volatile gases during carbonization. On the other hand, there is a hypothesis that proliferating in temperature make increases biochar porosity and also promotes water adsorption capacity.

Dugdug *et al*. (2018) concluded that the P adsorption capacity of biochar was dependent on the biochar type and soluble element concentrations in the biochar. Cation concentrations in the biochar can provide positive charges on the surface and lead to bridges between $PO_4{}^{3-}$ ions and soil colloid as surface precipitation (Shepherd *et al*., 2017). Zero point of charge of biochar is between 2.0 and 3.5 (Mukherjee *et al*., 2011). Surface charge of biochar becomes negative when the pH of the soil solution is greater than the zero point of charge.

Biochar Effects on Physical properties of Salt Affected soil

The elevated levels of Na in soil can break soil aggregates because of slaking, swelling and dispersion of clay as elucidated by the diffuse double layer (DDL) theory (Dahlawi *et al*., 2018). Swelling and dispersion cause surface crusting and hard setting of soil, thus adversely affecting infiltration and hydraulic conductivity (Oster and Jayawardane, 1998). Even though high Na content

(SAR=13 or ESP =15) negatively influences swelling and dispersion, high electrolyte concentration in soil solution (ECe = 1.5 dS m^{-1}) increases soil flocculation (Quirk, 2011). High salinity of irrigation water or soil solution pushes adsorbed cations closer to the surface of the soil particles, keeping soil aggregates together and thus maintaining good porosity to help improve the air and water conducting properties of salt-affected soils (Barbour, 1998). Therefore, removal of Na along with a moderate increase in electrolyte concentration is imperative for improving the physical properties of saline-sodic or sodic soils (Amini *et al*., 2016).

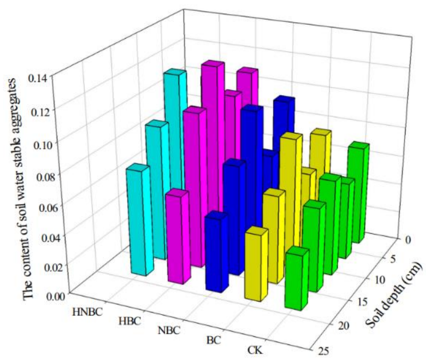

Fig. 1. Soil water stable macro aggregate contents in different soil layers after adding biochar and modified biochar treatments (Source : Duan*et al*., 2018)

Biochar can also improve the structure of salt-affected soils through its influence on the structure-building processes in soil such as aggregation, through improving above and below ground plant growth that ultimately impact the root zone processes and activity of soil microorganisms (Kolton *et al*., 2016). The organic molecules help to bind polyvalent cations and clay particles to improve aggregation in degraded salt-affected soils (Amini *et al*., 2016). Kim *et al*. (2016) reported an increase in the percentage of water-stable aggregates in biochar amended salt affected soils, most probably due to an increase in soil organic C content. Chaganti *et al*. (2015), through a series of lab incubation and column leaching experiments, showed that biochar improved aggregation and increased saturated hydraulic conductivity of saline-sodic soil mainly through increasing the Ca content in soil. Biochar addition considerably decreased clay dispersion and aggregate disintegration and increased infiltration rate in a noncalcareous loamy sand, whereas, in calcareous loam soil, it did not show any effect on the final infiltration rate (Abrol *et al*., 2016).

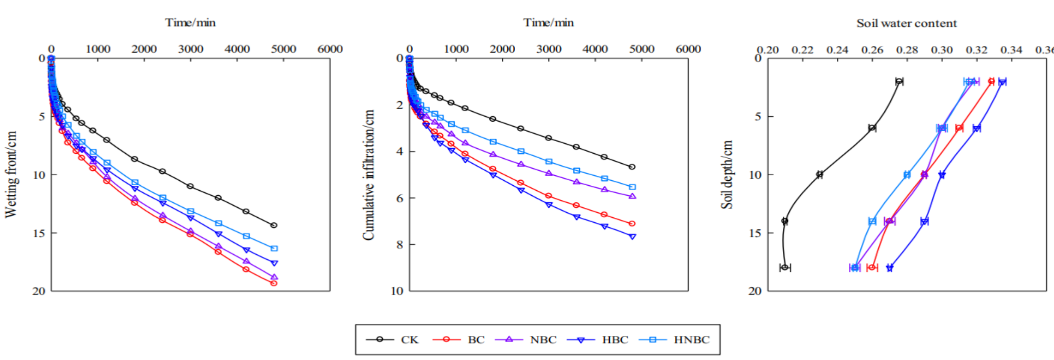

Fig. 2. Infiltration characteristics of soil after adding biochar and modified biochar treatments (Source: Sun *et al*., 2018)

Biochar Effects on Physico-chemical properties of Salt Affected soil

The application of biochar to soils can affect the pH of the soil that affects soil interaction such as adsorption and desorption of P ions as well as the precipitation and dissolution of P minerals (Borno*et al*., 2018). Biochar may also form an organic-inorganic complex in some form together with soil minerals (Zhuang*et al*., 2018). The pH of soil could decrease when low-pH biochar is added. Another explanation for the pH reduction in saline soil was due to the high CEC of biochar added. The high CEC of biochar promoted the adsorption of cations such as K+, Ca^{2+} and Mg^{2+} by the plants, resulting in hydrogen ions (H^+) release from the root zone to compensate charge balance (Hinsinger *et al*., 2003). Additionally, the proliferation of acid producing soil microorganisms in biochar-amended soils may decrease soil pH (Kim *et al*., 2016).

Biochar has high surface charge density and high surface area per unit mass, application of biochar increased soil CEC (Atkinson *et al*., 2010) which increased the exchange sites of soil colloids and adsorption of a wide range of ions in soils (Laird *et al*. 2010). Cation exchange capacity of biochar is closely related to surface functional groups such as carboxylic and phenolic OH groups (Liu *et al*., 2013) but varies with feedstock and combustion conditions (Wiedner*et al*., 2013). Gunarathne*et al*. (2020) have concluded that the wood chip biochar (produced at 500°C) is the most effective in mitigating soil salinity through leaching under excessive irrigation conditions. Huang *et al*. (2019) reported a significant decrease in soil EC by 9.8 - 36.5% at incorporation zoneas compared to the non-treated soil.

Table 1. Properties of modified biochar samples (Source: Sun *et al*., 2018)

Biochar	C%	H%	O%	N%	O/C	SSA ($m^2 g^{-1}$)	CEC (c mol kg^{-1})	pH (BC)	pH Soil + BC
BC	85.75	0.47	2.04	0.60	0.024	195.3	259.1	9.39	8.22
NBC	87.63	0.74	0.67	0.39	0.008	407.5	247.9	9.73	8.30
HBC	86.15	0.70	4.56	0.61	0.053	248.4	272.1	3.06	8.09
HNBC	91.98	1.33	5.68	0.32	0.062	461.4	296.8	3.25	8.15

According to Chaganti *et al*. (2015), biochar could reduce the ESP by providing Ca^{2+} ions to replace Na^+ in saline soil. The amendment of soil with biochar could improve soil structure and porosity, which promoting the leaching of Na^+ and leading to lower ESP or SAR of saline soil (Yue *et al*., 2016). Yue *et al*. (2016) reported that the biocharamended columns discharged efflux 24 to 40 days earlier, with that efflux having EC decreased to 5 dS m^{-1} 56 to 62 days earlier, than the control without biochar. Chaganti *et al*. (2015) also noted measurable decreases in ECE of a saline-sodic soil by 84, 83 and 82% under, respectively, biochar, biosolids compost and green waste compost compared to the non-amended control soil. While, it was found that acidic biochar increased hydraulic conductivity more significantly than the alkaline biochar, which was ascribed to the lower pH of acidic biochar that might have decreased the net negative surface charge, resulting in flocculation of soil (Kumari *et al*., 2016). Therefore, designer biochar with required properties such as more Ca, less Na and low pH (produced by controlling pyrolysis temperature and duration, blending different biochar feedstocks, selecting feedstock with more Ca and less Na and/or activating with different salts and acids) or pre-testing of biochar for target objectives, could be studied for the improvement of salt-affected soils.

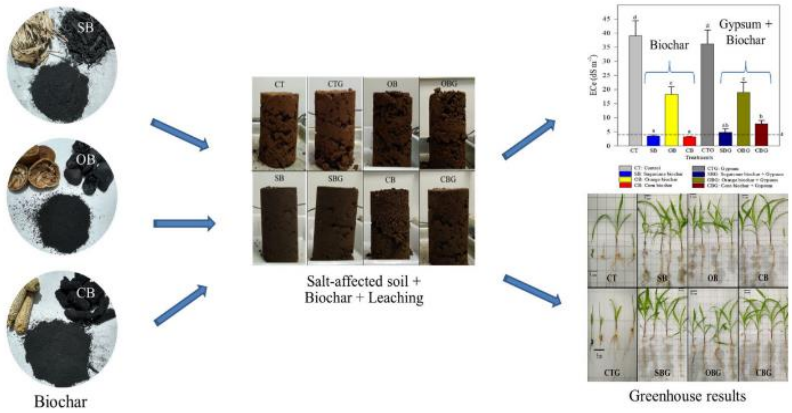

Fig. 3. Effectiveness of different biochars in remediating a salt-affected (biochars from sugarcane bagasse (SB), orange bagasse (OB), and corncob (CB) were applied alone and in the presence of gypsum (G) to test their potential

(Source :Biocharhttps://doi.org/10.1007/s42773-020-00084-w)

The effectiveness of amendments in reducing soil sodicity was in the order of PMB (9.3%) < GP (12.6%) < Saw dust biochar (21.9) = palm fiber biochar (21.9%), poultry manure biochar (PMB) and poultry manure (PM) were the organic amendments applied at gypsum requirement rate of 4.78 t ha^{-1}. SDB and PFB reduced soil sodicity below the minimum threshold of ESP 15 (Sappor*et al*., 2017).

Biochar Effects on chemical properties of Salt Affected soil

Physical adsorption is a process in which biochar utilises its surface characteristics such as surface area and porosity so that the salt ion could be adsorbed onto the surface of biochar or diffused into its micropores. Rostamian *et al*. (2018) have reported that the rice husk biochar with a mean pore size of 2.2 nm is effective in removing the Na^+ with a radius of about 0.178 nm. Aged biochar has a higher concentration of oxidized functional groups, CEC and anion exchange capacity (AEC) compared with fresh biochar (Mia *et al*., 2017b). Another potential mechanism of salt removal is ion exchange. Yavari *et al*. (2019) reported that palm oil empty fruit bunch (EFB) biochar has high CEC value of 83.90 c mol (p^+) kg^{-1} due to the presence of oxygenated and polar functional groups such as hydroxyl, carboxyl and carbonyl groups on the external surface of biochar.

At the time of pyrolysis, the Peptide-N bonds were transferred to N-heteroaromatic carbon composites, and the amount of Amide-N within the biochars reduced with increasing pyrolysis temperature. Ammonia (NH_3) volatilization is one of the major forms of nitrogen (N) losses from soil after N fertilization, especially in salt-affected soil, which leads to low N use efficiency. A study with biochar on Vertic Torrifluvents with a clay texture and EC (dS m^{-1}) of 12.65 showed that the addition of biochar decreased NH_3 volatilization by 10.8-20.9%. The results were consistent with the findings of Mandal *et al*. (2016), in which biochar reduced 40.8%-77.1% and 56.7%- 70.5% of accumulative NH_3 volatilization with poultry manure and urea treatment respectively, compared to no-biochar treatment. The pyrolysis of transformed organic P to inorganic P, resulting in the P enrichment of biochars. Pyrolysis produces sulfate, organosulfur, and sulfide through gasification results in 73–100% organosulfur (Yu *et al*., 2019). Sulfur-enriched biochar could be a potential soil amendment and fertilizer.

Table 2. Average decrease in soil pH, Total salts and sodium, bulk density with the BPC-PS amendments during wheat and maize crop (Source: Lashari *et al*., 2018)

Treatments	pH (H_2O)	Total soluble salts (g/kg)	Na^+ (g/kg)	Bulk density (g/cm^3)
CK (Control	8.02 + 0.21a	8.63 + 0.52a	5.52 + 0.14a	1.32 + 0.03a
BPC – PS1	7.84 + 0.18ab	5.45 + 0.28b	3.59 + 0.15b	1.22 + 0.01b
BPC – PS2	7.56 + 0.13b	4.99 + 0.15b	3.32 + 0.06b	1.17 + 0.01c

The different letters in the same column indicate significant differences ($p< 0.05$) between the treatments mean

Effect of biochar on macronutrient availability in salt-affected soils

Given that biochar is produced from organic wastes, it contains variable amounts of plant nutrients with varying nutrient release rates hence, upon additionto soil, biochar may improve the fertility status of salt-affected soils and the nutrient status of plants grown in these soils (Chan *et al*., 2008). Biochar can increase the availability and uptake of P in salt affected soils by directly acting as a source of P and indirectly by improving conditions of the growth medium (especially soil organic carbon) conducive for increased availability, uptake and translocation from shoots to grains (Lashari *et al*., 2013) or increasing the relative abundance and distribution of phosphate-solubilizing bacteria such as *Thiobacillus*, *Pseudomonas* and *Flavobacterium* in soils (Liu *et al*., 2017).

Biochar application can improve nutrient status, especially of N, in saline soils through its impact on the abundance and activities of bacteria that enhance nutrient transformations and hence availability (Bhaduri *et al*., 2016). Biochar can decrease N losses to atmosphere as NH_3 and N_2O through increased adsorption of ammonium onto biochar particles (Esfandbod *et al*., 2017) and also decreased nitrification and subsequently denitrification (Sun *et al*., 2018). A significantly lower NH_3 volatilization was reported from highly saline and alkaline bauxite residue sandy soils amended with acidic biochar (pH 3.9) compared to the application of alkaline (pH 9.6–10.8) biochar (Esfandbod *et al*., 2017).

Biochar addition can result in increasing available Kin salt-affected soils and is considered one of the most important underlying mechanisms for the biochar-induced increase in growth of salt-stressed plants (Abbas *et al*., 2017a). Lin *et al*. (2015) showed that biochar application (16 t ha^{-1}) to the saline soil did not influence the soil pH and the concentrations of salt and exchangeable Na, Ca and Mg, but it increased exchangeable K concentration by 44%. However, biochar type and soil properties could play an important role in altering K availability (Taghavimehr, 2015).

However, biochar can retain nutrients through binding to inner surfaces, and its application could increase nutrient availability through decreasing nutrient fixation onto soil colloids (Hammer *et al*., 2014). The removal of P using a low-cost sorbent, such as biochar, has gained more attention as a potential means of recovery/recycling of P (Antunes *et al*., 2018). Use of biochar as a chemical sorbent in agroecosystems and mitigation of salt stress in agricultural lands has economic and environmental benefits.

Effect of biochar on micronutrients in salt-affected soils

Calcareous saline-sodic and sodic soils are particularly deficient in zinc (Mehrotra *et al*., 1986). Molybdenum (Mo) in soils exists as anions, and its solubility and availability increase with increasing pH as in saline-sodic and sodic soils. Similarly, boron (B) dissolution and availability increase with pH; above pH 9.0, B becomes toxic to many crop plants (Curtin and Naidu, 1998; Naidu and Rengasamy, 1993). The application of alkaline biochar to saline-sodic and sodic soils may aggravate the problem of low availability of iron (Fe), Zn, copper (Cu), and Mn and increase toxicity of B; however, there is little published information on the role of biochar in affecting solubility and availability of micronutrients in salt affected soils (Drake *et al*., 2016). There is a need to assess the impact of various types of biochar (especially acidic and alkaline ones) on the behavior and dynamics of the pH sensitive microelements in such soils.

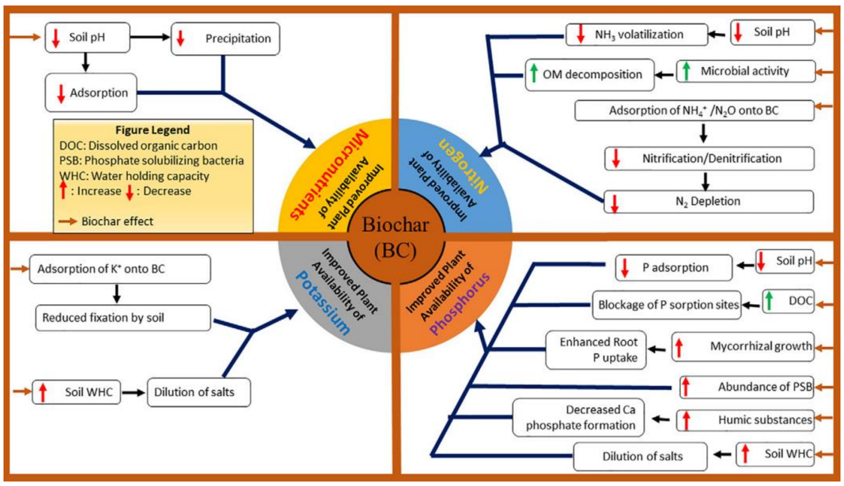

Fig. 4. Schematic presentation of the favourable effects of acidic biochar on plant available nutrients in soil (Source: Saifullah *et al*., 2018).

Soil fertility index

Compared to the control, incorporation of 5, 10, and 19 ton ha^{-1} wood sawdust biochar increased SFI by 21.15%, 27.37%, and 43.4%, respectively (Mahmoud *et al*., 2019).

Biochar Effects on Biological properties of Salt Affected soil

The interaction between nutrients may also have a great influence on microorganism-mediated (flux change of CO_2) processes (Zhang *et al*., 2014). Besides directly causing an increase in microbial biomass and enhanced activity, exogenous carbon input can also increase the supply of other elements needed by the plant, and moreover, it has an indirect influence on the vital activities of microorganisms and the carbon cycling processes they participate in, e.g. SOM mineralization (He *et al*., 2017). Excessive salts present on the soil exchange complex and/or in soil solution can disrupt nodule formation by decreasing the population of *Rhizobia* in soil or by impairing their capacity to infect root hairs (Soussi *et al*., 1998). Biochar addition in salt-affected soils can improve the nutrient acquisition capacity of plants by improving biochar-root interactions (Jeffery *et al*., 2017) and enhancing soil exploration through its positive impact on growth and activity of mycorrhizal fungi (Abiven *et al*., 2015). Biochar together with mycorhizal fungal inoculation resulted in an additional plant yield increase under saline conditions compared to the application of each alone and the yield increase was attributed to increased P and Mn uptake and an improved Na/K ratio in salinity stressed plants treated with mycorrhizal fungi and biochar addition (Hammer *et al*., 2014).

Changes in soil enzymes Catalase activity of soil is strongly linked with the respiration of soil aerobic microorganisms, soil fertility and organic matter content. It also acts as an indicator for redox potential of soil. Moreover, catalase is one of the enzymes showing the highest sensitivity to the changes in the environment, including the salinity changes (Guangming *et al*. 2017). Therefore, the evaluation of catalase activity provides a better indication of soil salinity changes. Among the five types of organic amendments used, 300 BC was proved effective in accomplishing the highest increment in alkaline phosphatase activity and TOC content, second most increase for acid phosphatase, and second most reduction in EC (Agnieszka *et al*., 2020).

Biochar effects on the abundance of ammonia oxidizers The abundance of the AOA-amoA genes ranged between 4.3×10^3 and 4.8×10^4 copies g^{-1} soil in the CK and between 6.6×10^2 and 4.2×10^4 copies g^{-1} soil the in biochar treatments (Yanjing Song *et al*., 2014).Soil respiration results reveal the biological activity under specific ecosystems. The lowered soil respiration due to reduced microbial load, as a consequence of salinity, was noted in CTR (control). Similarly, DI (digestate) fusion with biochars also improved the CO_2 release over the individual groups, as the nonpyrolyzed organic residue has greater degradability than biochar and SOM in a single ecosystem (Cui *et al*., 2017). It is accredited to the reduced availability of labile C in the presence of biochar occurs via a pore-filling mechanism, where the selective absorption of aliphatic C portions takes place from natural SOM (Smebye *et al*., 2016). This phenomenon results in adding up of recalcitrant C to residual soil pools, which eventually lowers the mineralization of SOC. The results demonstrated that the changes in the soil ecosystem impact the microbial C use efficiency, which decides to proliferate instead of respiration, are controlled by nutrient stoichiometry, substrate availability and physiological status of soil microbiota (Manzoni *et al*., 2012).

Biochar Effects on Nutrient additions and Carbon sequestration

Based on existing research results, we deduce that the changes in ecological stoichiometric characteristics of SOM caused by the addition of biochar and nutrients will certainly change the contributions of soil microbial biomass and soil microbial residues to SOC sequestration, and moreover, this can lead to changes in SOC reserves. The concentrations of labile C (C_1) ranged from 8.33 to 101 μg/g in different treatments, which only accounted for a small proportion (0.5%) in the total carbon pool (Sun *et al*., 2018).

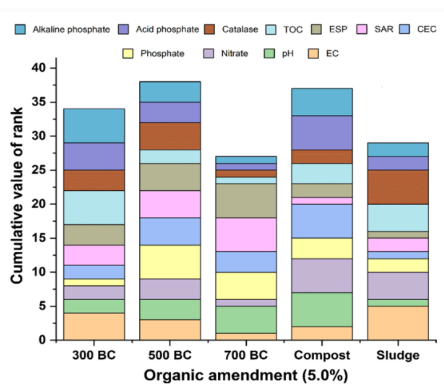

Fig. 5. Overall comparison of potentials among the organic amendments at a 5.0% application rate for the reclamation of salt affected soil (Source: Agnieszka *et al*., 2020)

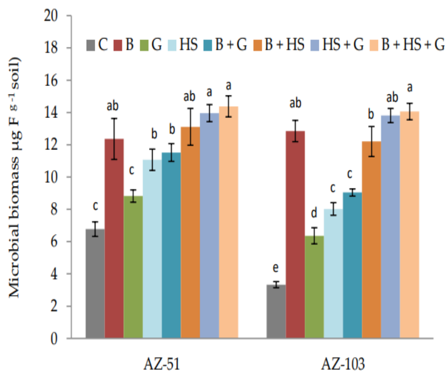

Fig. 6. Microbial biomass in saline – sodic soil after the application of amendments. C: Control; B: Biochar; G: Gypsum; HS : Humic Substance; and combinations (Source : Duan*et al*., 2018)

Effect of biochar on growth, physiological and biochemical processes in plants on salt-affected soils

With respect to number of leaves per shoot, the results showed that application of biochar at 100% recorded the larger number of leaves/shoot followed by compost at 25% + biochar at 75% in both seasons (50 & 51 and 44.67 & 45.22 leaves/shoot), respectively. Biochar amendment proved effective under the stress condition, 1% biochar showed 7.3%, 5.6% and 8.4% increase, while 2% biochar level showed 12%, 10.7% and 17% increase in seedling vigor index at 50 mM, 100 mM and 150 mM salt concentration, respectively (Ghafoor*et al*., 2004).

Biochar, depending upon feedstock, may increase K concentration in soils, and such an increase in salt-affected soils to counteract the adverse impacts of Na is considered one of the major benefits associated with biochar application (Abbas *et al*., 2017b). Interestingly, the biochar addition significantly increased the exch. K concentration (by 44% over control) and increase the K:Na ratio in plants, which improved the plant salt tolerance and thus increased plant growth.

Biochar effects on salt stress alleviation

Under the saline condition, 1% biochar treatment showed 19.2%, 21% and 25% decrease in proline content while most obvious effect was shown by 2% biochar with decrease of 36%, 47% and 51% at 50 mM, 100 mM and 150 mM NaCl solution application, respectively. While, in stress-exposed plants, biochar also proved quite effective, and showed 25% decrease at 1% biochar level and 27% decrease in soluble sugar at 2% biochar level at 150 mm salt concentration. Biochar amendment also decreased the activity of SOD under both normal and saline conditions, respectively. Under the stress condition, biochar application resulted in 6.5% 9.2% and 10.7% decrease in SOD activity at 1% level and 10.5%, 11.11% and 15.3% decrease at 2% level under 50 mM, 100 mM and 150 mM salt concentration, respectively (Sidra Kanwal*et al*., 2017). Organic amendments have been shown to alleviate salt stress in plants by regulating the synthesis of antioxidant enzymes in plants (Tartoura*et al*. 2014). Adam *et al*. (2021) found that rice plant with a low quantity of proline (μg/g) was produced when using Typha for non-saline (25.62), and a large quantity of proline was found when rice bran was applied in both saline-sodic (128.07) and saline soil (112.28). Biochar decreased ABA concentrations in leaf and xylem sap of salt-stressed potato (Akhtar *et al*. 2015a). Given paucity of data on this aspect, further in-depth field studies are needed to investigate the biochar-plant species interactions in salt-affected soils.

Biochar addition, under salt stress at both levels (5 and 10%) efficiently increased the LRWC by 45.2% and 39.1%, respectively, relative to the salt stressed plants with no application of biochar. Under saline-water irrigation, the increase in chlorophyll b content was 26.9% at 5% biochar level and 67.3% at 10% biochar level (Raziye*et al*., 2020).

Biochar Effects on Elemental compositionand Yield of Crops on Salt Affected soil

Biochar application also reduces sodium uptake by plants through transient Na^+ binding due to its high adsorption capacity and by releasing nutrients (K^+, Ca^{2+} and Mg^{2+}) into the soil solution (Feng *et al*., 2018). Inal *et al*. (2015) found that nitrogen concentrations of maize plants were increased by biochar application, where the greatest application rates of biochar at 20 g kg^{-1} gave the largest N concentrations in maize plants. Similar significant increases were observed in the P concentration of maize plants after 10 and 20 g kg^{-1} of biochar.

The application of wood sawdust biochar to the soil at 5, 10, and 19 t ha^{-1} increased grain yield by 20%, 25%, 32%, respectively, compared to the control. The application 19 ton ha^{-1} BW increased N, P, and K uptake by 60.97%, 55.89%, and 68.54%, respectively (Mahmoud *et al*., 2019).Soil amended with BC @ 2% & 6% showed an increased concentration of plant N content by 37 and 26%, respectively (Dilfuza *et al*., 2021).Biochar application @ 30 g/kg soil significantly increased the drymass in different rice plant parts like leaf, sheath, stem, panicle to 10.95, 18.1, 19.55 and 60.6 g/hill against 9.05, 15.35, 16.3 and 43.05 g/hill in no-biochar treatment (Feng *et al*., 2018).

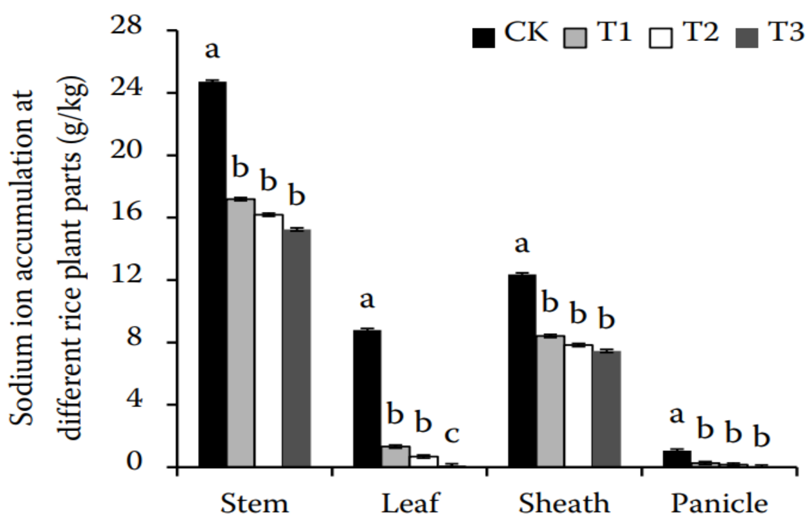

Fig. 7. Effects of biochar application on sodium ion accumulation at different rice plant parts (Feng *et al*., 2018).

T1 – 15 g; T2- 30 g; T3- 45 g of biochar per kilogram soil; CK - Control

Influence Biochar Amendments on Metabolic Responses to Salinity Stress

Not only by direct effects, biochar has also been shown to improve plant growth in salt-affected soils because of many indirect benefits including reduction in the availability and uptake of toxic salts such as Na through adsorption onto biochar surfaces, or physical entrapment of Na in fine pores of biochars, or enhanced leaching from soil profile (Thomas *et al*., 2013) and reduction in oxidation stress through degradation of O^{2-} and H_2O_2 concentration (Kim *et al*., 2016), reduction in osmotic stress through improving water holding capacity and thus availability of water (Rizwan *et al*., 2018), lower production of phytohormones (Lashari *et al*., 2015), improvement in stomatal density and conductance (Thomas *et al*., 2013), improvement in seed germination (Zheng *et al*., 2017) and the promotion of microbial activities and a bacterial community shift toward the beneficial taxa in the rhizosphere (Zheng *et al*., 2017).

Electrolytic leakage

Under salinity stress, an increase in the accumulation of salts in the plant cells occurs, which results in an increase in cell wall permeability. Because of increased cell wall permeability, a substantial increase in electrolyte leakage occurs from the stricken cells (Ashraf and Harris, 2004). Biochar has high adsorption capacity, which helps to mitigate the detrimental impact of salinity by minimizing the uptake of Na^+ (Akhtar *et al*., 2015a). Due to this function of biochar, there was less accumulation of salts in plant tissues, resulting in lower electrolyte leakage in treatments amended with biochar in comparison with the control (non-biochar), even under higher salinity levels.

II. Biochar for remediating poor quality water

In arid and semi-arid ecosystems, water scarcity is becoming a worldwide problem of increasing severity (Abdel kader*et al*., 2018). To overcome this, lower-quality water, such as saline water, is being widely used. However, using the saline water causes a number of negative consequences such as increased soil salinity and chemical toxicity and a range of adverse chemical, physical, and biological effects on the soil as well plant properties. Organic soil amendments such as biochar improve the physical, chemical, and biological properties of soils under saline conditions.Saline water without biochar application has characterized the lowest crop yield of 3.07 tha^{-1}. However, biochar addition increased the wheat yield from 3.07 to 3.47 t ha^{-1} under saline water conditions. These results indicated that there is at least potential to achieve over 90% of freshwater wheat yield when saline irrigation water is used with biochar (Prasad *et al*., 2020).

Tomato shoot fresh weight under saline water irrigation was increased by 91% by BC-1 and 113.7% with BC-2 as compared to the treatment where application of saline water was made. Whereas, increase in shoot dry weight under the same conditions was 65.4% and 74.8%, respectively. When comparing the treatments, 5% biochar (BC-1) increased the plant height by 43.1%/38.6% (Raziye*et al*., 2020).

Water Productivity

Using groundwater as an alternative source of water is considered as one of the more suitable ways to address food insecurity problems in arid and semi-arid countries. However, crop and water productivity are negatively impacted by groundwater salinity. Biochar addition enhanced the water productivity under saline conditions to nearly the same productivity found when non-saline water was applied due to its ability to adsorb water particles and various ions. As a salt adsorbent, biochar could remove/isolate salt ions e.g. Na through physiochemical adsorption to mitigate the salinity of brackish water.

Leachate studies

Considering the initial soil ECe of 74.9 dS m^{-1}, the reduction was 96% (SB and CB), 92% (CBG and SBG), 77% (OB and OBG), and 50% (CGT and CT). Based on the threshold value of 4 dS m^{-1} (Richards, 1954), only SB and CB effectively reduced ECe. In contrast, sole biochar (CB=SB) significantly favored sodium leaching and reduced ESP by approximately 80%, lowering ESP values to below 15%, the threshold value determined by Richards (1954). The gypsum (G) treatment increased soil Ks by 51.2% relative to that of the CK (control), and the GBC treatment resulted in an even greater increase in soil Ks. The concentration of Na^+ of the leachate decreased sharply after the first leaching episode for all treatments (Yu e*et al*., 2020)

Future research thrust on biochar as an amendment for salt-affected soils

֍ For using biochar in salt-affected soils as an effective ameliorant, understanding of biochar-soil-plant-microbial interactions in various types of salt-affected soils is a prerequisite ֍ More focus should be given for the studies involving combined application of biochar with other organic and inorganic amendments (especially gypsum) ֍ Because the use of poor quality (brackish) water is increasing at alarming rates in many parts of the country, it becomes imperative to conduct studies on the potential benefits of biochar in such situations. ֍ The type and amount of biochar applied must be suitable for a specific type of salt-affected soils necessitates further in-depth field studies. ֍ The effect of biochar on redistribution of salts at various depths of the soil profile warrants detailed field studies. ֍ Impact of biochar on dissolution of native calcite in calcareous salt-affected soilsneeds thorough investigation under field-based settings in calcareous and non-calcareous salt affected soils using different types of biochar. ֍ Making of biochar from crop residues, which are otherwise burnt, sustains environmental quality by preventing GHG emission on one side and sustains soil and water quality when used as an amendment on salt affected soils and waters. The cost-benefit analysis of using biochar in salt-affected soils is required forwide adoption.

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