ISSN 0972-1584

26 • No. 1 • 2008

Journal of the Indian Society of Coastal Agricultural Research

Advancement in Research on Coastal Agriculture

ISCAR

Publication of
Indian Society of Coastal Agricultural Research
www.iscar.org.in

ISSN 0972-1584

Journal of THE INDIAN SOCIETY OF COASTAL AGRICULTURAL RESEARCH

Volume 26 | 2008 | Number 1

Special Issue on

International Symposium on Management of Coastal Ecosystem : Technological Advancement and Livelihood Security

held in celebration of the Silver Jubilee Year of the Society

Kolkata, West Bengal, India, 27 - 30 October, 2007

INDIAN SOCIETY OF COASTAL AGRICULTURAL RESEARCH

(Founded 1982)

Regn. No. T/40093 of 1982-83

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Acknowledgement

The Indian Society of Coastal Agricultural Research (ISCAR) is grateful to the Indian Council of Agricultural Research (ICAR), New Delhi for recognizing the contribution of ISCAR for disseminating the research findings on the various aspects of Coastal Agriculture through the journal (Journal of the Indian Society of Coastal Agricultural Research) published by the Society. The Society is highly indebted to ICAR for providing necessary financial assistances for publication of the Journal.

ISSN 0972-1584

JOURNAL
OF
THE INDIAN SOCIETY OF COASTAL AGRICULTURAL RESEARCH

VOLUME 26 | 2008 | NUMBER 1

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Published by the Hony. Secretary, Indian Society of Coastal Agricultural Research Canning Town (743 329) and Printed by Media, Kolkata - 700 029, Phone : 98306 10609

J. Indian Soc. Coastal agric. Res., 26(1), 1-4, 2008 **Address by Guest-of-Honour**

Management of Coastal Ecosystem – Environmental Issues

SAILEN SARKAR

Hon'ble Minister
Department of Parliamentary Affairs & Environment
Government of West Bengal, India

Global climatic change has its own paradigm shift in its research methodologies and developmental aspects. India being the agri-economy based country, it is quite obvious that we need to depend heavily upon the agricultural sector and its productivity. On the other hand, agriculture and environment are mutually interlinked with each other in its entire operation and execution towards the economy regeneration of any country and with all likelihood it is relevant to Indian context also. Agriculture is likely to respond initially to climate change through a series of automatic mechanisms. Some of these mechanisms are biological, and others are routine adjustments by farmers and markets. Climate change will impact agriculture by causing damage and gain at scales ranging from individual plants or animals to global trade networks. At the plant or field scale, climate changes to affect crop and animal physiology. Climate change involving alterations in temperature, precipitation and sea level as well as increased incidence of ultra-violet radiation (400 nm to 10nm) are distinct possibilities in the not too distant future. Impact adaptation (agronomic and economic) are likely to extend to the farm and surrounding regional sensitive sectors – the assessment of climate change impacts on agriculture has thus acquired special significance. In developing countries like India, climate change could represent an additional stress on ecological and socioeconomic systems that are already facing tremendous pressures due to rapid urbanization, industrialization and economic development. With its huge and growing population, a 7500 km long densely populated and lowlying coastline, and an economy that is closely tied to its natural resource base, India is considerably vulnerable to the impacts of climate change.

Impacts of climate change on Indian agriculture

Agriculture and allied activities constitute the single largest component of India's economy, contributing nearly 27 percent of the total Gross Domestic Product (GDP) in the year 1999-2000. Agriculture exports account for 13 to 18 percent of total annual exports of the country. However, given that 62 percent of the cropped area is still dependent on rainfall, Indian agriculture continues to be fundamentally dependent on the weather. A few studies on the impact on agriculture have been reported for India in the IPCC Third Assessment Report. While there is report that decrease in rice yield by 3 to 15 percent under a scenario of 1.5°C rise in temperature and a 2 mm day^{-1} increase in precipitation exists, some other report reflects that yields of soybean in India would vary between -22 to 18 percent under different climate scenario considering $\pm$2 and $\pm$4°C change in temperature, $\pm$20 and $\pm$40 percent change in precipitation. Some estimation says that there is a decrease in rice yield at the rate of 0.71 t ha^{-1} with an increase in minimum temperature from 18°C to 19°C and a decrease 0.51 t ha^{-1} with a temperature increase at the rate of from 22°C to 23°C. Whereas, other estimates suggest that a 2°C increase in mean air temperature could decrease rice yield by about 0.75 t ha^{-1} in the high yielding areas and by about 0.06 t ha^{-1} in the low yielding coastal regions. Further, a 0.5°C increase in winter temperature would reduce wheat crop duration by seven days with consequent decrease in yield by 0.45 t ha^{-1}. An increase in winter temperature of 0.5°C would thereby translate into a 10 percent reduction in wheat production in the high yielding states of Punjab, Haryana and Uttar Pradesh. Hence, potential rise in temperature will have disastrous consequences on wheat production in India. The study showed that for rice, increasing mean daily temperature would decrease the period from transplantation to maturity. Such reduction in duration is often accompanied by decreasing crop yields. There are, however, genotypic differences in per day yield potential. Breeder can consciously select strains with a high per day production. Increased level of CO_2 would increase photosynthetic rate and hence the dry matter production but increase in temperature might reduce crop duration and thereby increase the yield.

Simulation of irrigation was studied for Pantnagar district under doubled CO_2 and increased temperature. The study concluded that the impact on rice production would be positive in the absence of nutrient and water limitations. Another crop simulation study estimated that under elevated (2 x CO_2=720 ppm) carbon dioxide condition the wheat yields could decrease by 28 percent to 68 percent without considering the carbon dioxide fertilization effects. Researches suggest that in North India, a 1°C rise in mean temperature would have no significant effect on wheat yields, while a 2°C increase would reduce yields in most places. A recent study have examined the adaptation options while estimating the agricultural impacts. The study showed that even with adaptation by farmers of their cropping patterns and inputs, in response to climate change, the losses would remain significant. The loss in farm level net revenue is estimated to range between 9 and 25 percent for a temperature rise of 2°C to 3.5°C.

Estimation suggests there that India's climate could become warmer under conditions of increased atmospheric carbon dioxide. The average temperature change is predicted to be in the range of 2.33°C to 4.78°C with doubling of CO_2 concentrations. It is also likely that there will be an increase in the frequency of heavy rainfall events in South and Southeast Asia. Some researchers presented a climate change scenario for the Indian subcontinent, taking projected emissions of greenhouse gases and sulphate aerosols into account. It predicts an increase in annual mean maximum and minimum surface air temperatures of 0.7°C and 1.0°C, respectively over land in the 2040s with respect to the 1980s. Since the warming over land is projected to be lower in magnitude than that over the adjoining ocean, the land-sea thermal contrast that drives the monsoon mechanism could possibly decline. However, there continues to be considerable uncertainty about the impacts of aerosols on the monsoon.

Indian agriculture – strengths and challenges

Strong strides were made in increasing the production in the past 50 years mainly due to adoption of high yielding varieties (HYV) and other technological developments. Subsistence agriculture with small land holdings and skewed distribution of land made wide variation in regional productivities. Majority still depends on rainfed agriculture. Significant proportion of population still reels under poverty, malnutrition and chronic hunger. Under emerging economic regime of World Trade Organization (WTO) economic liberalization is an imposing challenge on us to sustain the productivity.

Coastal ecosystem

Coastal areas are prone to threats from natural causes such as tidal surges and sea level rise. Each year an estimated 46 million people risk flooding from storm surges. Coasts in many countries currently face severe problems of sea level rise as a consequence of climate change, leading to potential impacts on ecosystems, human lives and properties, and coastal infrastructure. The worst scenario projects a sea level rise of 95 cm by the year 2100 with large local differences (resulting from tides, wind and atmospheric pressure patterns, changes in ocean circulation, vertical movements of continents, etc.) influencing the relative sea level phenomena. The impacts of sea level rise are therefore expected to be more local than global. The relative change of sea and land is the main factor. Many cities, for instance, suffer from land subsidence as a result of groundwater withdrawal. This may be compounded by sea level rise, especially since rates of subsidence may exceed the rate of sea level rise between now and 2100. Under the worst scenario, the majority of the people who would be affected live in China (72 million people), Bangladesh (13 million people with loss of 16 percent of national rice production) and Egypt (6 million people with 12 to 15 percent loss of agricultural land). Between 0.3 percent (Venezuela) and 100 percent (Kiribati and the Marshall Islands) of the population would be affected in these areas. Even more significant than the direct loss of land caused by the sea rising are the associated indirect factors, including erosion patterns and damage to coastal infrastructure, salinization of wells, suboptimal functioning of the sewage system of coastal cities (with resulting health impacts), loss of littoral ecosystems, and loss of biotic resources. In coastal areas, and particularly deltas, factors such as modified ocean circulation patterns (and their impact on building and erosion of the coast), climate change in the catchment basin and change in coastal climate, not to mention changes in the frequency of extreme events, should be taken into account.

Destruction of habitats in coastal ecosystem is also caused by natural disasters, such as cyclones, hurricanes, typhoons, volcano, earthquakes and *tsunamis*. These factors can cause significant physical damage to reefs or move large amounts of ballast is also a source of oil, nutrients, and pathogen pollution.

In India government has set up a statutory body as 'Natural Disaster Management Authority' and is also considering the possibility of constructing a high wall all along the seashore, though some reservations from ecological considerations were expressed in certain quarters. Only 12 days back the Government of India has launched an accurate forecast system relating to *tsunami* disaster. The United Nations is expected to help in setting up a *tsunami* early warming network for the Indian Ocean similar to that for Pacific Ocean. Japan has one of the world's most advanced warning systems, using supercomputer linked by satellite to an array of seismic, pressure and tidal sensors to help forecasting about the size of waves approaching the coastline.

J. Indian Soc. Coastal agric. Res., 26(1), 5-11, 2008 **Presidential Address**

Sustainable Management of Coastal Ecosystem for Livelihood Security: A Global Perspective

J. S. P. YADAV[1]

President, Indian Society of Coastal Agricultural Research

Consequent to planned agricultural development with First Five Year Plan (1951-56) coupled with application of science and technology including improved seeds, use of fertilizers, irrigation application and better agronomic practices with focus on high input and high productivity, Indian agriculture made spectacular progress. As compared to 1950-51, the foodgrain production increased from 51 MT to 213 MT in 2001-02, oilseed production from 5.2 MT to 28.0 MT in 2005-06, sugarcane production from 57 MT to 299 MT in 1999-2000, cotton production from 3.0 million to 18.5 million bales in 2005-06, jute and mesta from 3.3 million to 10.8 million bales in 2005-06, milk production from about 20 MT to 91 MT in 2004-05, fish production from 0.75 MT to 6.4 MT in 2003-04, while fruit as well as vegetable production rose to 45.2 MT and 84.8 MT, respectively in 2002-03.The production of these commodities stands among first three positions at the global level.

In an attempt to augment agricultural production for meeting the demands of the fast swelling population, overexploitation and unwise management of the natural resources without regard to long term sustainability have led to resource degradation raising serious environmental concerns, on the one hand, and decline in productivity growth rate of all principal crops, on the other. The available data reveal that crop yields in India are much lower than even the world average. The major cause of concern is that both productivity and production of foodgrains, viz. rice, wheat, pulses, oilseeds, and sugarcane have shown stagnation during 2001-05. Besides, the net cultivated area in India has hovered around 140 M ha during the last 37 years although the population increase is still taking place at an alarming rate resulting in continuous drop in per capita land availability for agricultural use. Inspite of these facts, some prime farm lands are continually and possibly at increasing rate being diverted to non-agricultural use, mainly for industries, as evidenced from public protests in different parts of the country including this state. Because of sluggish growth in Indian agriculture, the contribution of agriculture sector towards GDP has dipped substantially and a serious agrarian crisis is already witnessed in several areas.

The food, nutrition and livelihood security is at a great risk. India has the largest number of malnutritioned children, women and men in the world with approximately 21.8 percent of population living below the poverty line. Although the World Food Summit targeted to reduce the number of world's hungry people to half by 2015 and the same reaffirmed by the Millenneum Development Goal, this will be difficult unless suitable measures are undertaken to avert the gloomy situation. According to the Planning Commission, India should produce 307.5 MT cereals, 29.8 MT pulses and 58.6 MT oilseeds by 2011-12. The Prime Minister Dr. Manmohan Singh has stressed that the country should double the foodgrain production to a level of 420 MT during this plan period. Moreover, the target of 9 percent GDP growth in the XIth Five Year Plan with double digit growth in the terminal year will need a sustained robust growth in agriculture which will also provide employment, alleviate poverty and improve livelihood to 115 million farming families.

In this context, it is imperative to harness the immense untapped potential available in the disadvantaged fragile ecosystems like coastal areas, hilly tracts and rainfed regions. The Indian Society of Coastal Agricultural Research has organized so far eight national seminars, wherein the constraints and opportunities of the coastal areas in India have been documented in considerable details. It is expected that acceleration of agricultural production in these areas with efficient management is possible. The Indian Society of Coastal Agricultural Research,

[1]Address : B-14, IARI Campus, Pusa, New Delhi - 110 012

which is completing its 25 years of existence and which is perhaps the only multidisciplinary professional society at the global level with focus on coastal agriculture and allied subjects, has ventured to organize the present international symposium to address the various challenging problems of the coastal ecosystem across the world and to make appropriate recommendations regarding technological advancement for ensuing livelihood security.

Coastal regulation zone (CRZ) in India

The coastal areas less than 10 meters above the mean sea level constitute only 2% of the global level, but they house 10% of the world's population and are vulnerable to the storm surges and increased intensity of tropical cyclones. As per the 1991 notification, the Coastal Regulation Zone (CRZ) in India extends upto 500 km from the high tides and includes the land between high tides and low tide lines. This area comprises coastal stretches of seas, bays, estuaries, creeks, rivers and backwaters, which are influenced by the tidal action in the landward side during the strong tide.

The CRZ is subdivided into 4 categories on the basis of ecological similarity, geomorphological features and demographic distribution. The CRZ I is ecologically sensitive to high tides, the CRZ II is largely urban and developed, the CRZ III is rural and undeveloped, and CRZ IV includes Andaman and Nicobar Islands. No development is permitted in CRZ I area, while development is allowed in CRZ II on the landward side of existing authorized structures. In CRZ III, land upto 200 meters from the high tide line is no-development zone and is mainly restricted to agriculture and essential use of local inhabitants. Construction of traditional dwellings is permitted between 200 and 500 meters of the high tide line.

The management of these CRZ areas entails enormous difficulties because of ambiguities in demarcating high tide line and also in distinguishing developed areas. According to 2005 report of M.S. Swaminathan Committee considerable confusion exists among different agencies regarding definition of high tide level. These issues, therefore, need to be resolved to facilitate proper administration of these CRZ areas.

The quality of coastal ecosystem is being threatened by contamination and degradation. With increasing pollution of the oceans, the mammals like seals, whales and dolphins are affected and coral reefs as well as other habitats get destroyed. According to the Inter-Governmental Oceanographic Commission of UNESCO, about 90% of resources in minerals, oil and natural gas can be exploited from the sea beds of the oceans.

Rainwater conservation and management

Despite high rainfall in certain coastal areas such as in Kerala, the widespread occurrence of water stress faced in the non-rainy season affects adversely agricultural production. Moreover, excessive withdrawal of ground water in certain areas leads to intrusion of salty seawater, contaminating the aquifer. This has negative effect on crop productivity and food security. Therefore, for achieving higher production, livelihood and income, maximum conservation of rainwater and recharging of ground water assume significant importance. In many areas water balance analysis reveals substantial excess of rainwater, thereby offering enough scope for storing excess rainwater and for using the stored water for much needed irrigation. Rainwater harvesting also helps in recharging ground water. In this context, water harvesting has been assigned high importance through integrated watershed management programmes to promote intensification and diversification of agriculture, and also to safeguard against risks arising from drought.

An innovative farmer named R. Natesan from near Chennai in Tamil Nadu constructed check dams to trap runoff water and dug about 14 ponds in his 26 acre farm to harvest rainwater. The bottom of the pits was mulched with dry coconut leaves to prevent deep seepage loss and also to help recharge his two walls in the farm. He planted 450 coconut trees on his land and grew ornamental fish in the pits to obtain additional income. The farmer could harvest about 70,000-80,000 coconuts as against only 18,000-20,000 five years back. According to his experience, successful farming lies in minimum use of water, proper soil and water conservation measures, lesser use of chemical fertilizers, and good marketing facility for the produce.

Prime Minister Dr. Manmohan Singh, while inaugurating the first meeting of newly constituted Advisory Council for Artificial Recharge of Ground Water on July 22, 2006 in Delhi stressed that ground water management holds the key to water scarcity and called for nationwide people's campaign for recharging ground water levels that have dropped down by over 4 meters in 506 districts over the last

20 years in India. While inaugurating the first National Congress on Ground Water, organized by the Union Ministry of Water Resources in New Delhi on September 11, 2007, Dr. Manmohan Singh elaborated the importance of efficient, economic and rational use of water, and indicated threats to water supply sources due to the climate change. He advocated the need for conservation and replenishment of water resources. In this regard, he lauded the example of neighbourhood-based strategy adopted in Chennai in Tamil Nadu for rainwater harvesting.

Production system

The coastal areas in countries like India are endowed with abundant sunshine, solar as well as wind energy, precipitation, diverse soils, physiography, climate, etc. and therefore, have tremendous opportunities for supporting a host of perennial and annual crops like trees, fruit plants, cereals, root crops, pulses, oilseeds, commercial crops, vegetables, etc. In addition, the prospects of fishery, poultry, animal husbandry, sericulture, mushroom cultivation, bee-keeping and dairying are also enormous. Rice based cropping systems are more dominant in the coastal plain tracts. In a field experiment on deep poorly drained alluvial soil in Balipatna Block in Orissa having average annual rainfall of 1480 mm, a modified soil physical environment through 5m x 30m alternate raised and sunken beds was studied in 2002-04 for seven different cropping systems. The highest rice equivalent, water expense efficiency, net water productivity, net returns, and B/C ratio were achieved with rice-fish in the sunken bed and pointed gourd + snake gourd in the raised bed system. Many developing countries in Asia, Africa and Latin America are reported to possess rich genetic resources of tuber and root crops, and there is significant opportunity for exchange of plant genetic materials.

Certain plantation crops, especially coconut, arecanut and cocoa have received major attention in the coastal areas. Mixed and intercrops in the coconut and arecanut based cropping system have helped in augmenting overall production capacity as well as in improving economic returns of the farmers in a sustainable manner. The coconut based farming system comprising coconut, grass, dairy, poultry and fishery has proved more economical and sustainable. Several benefits relating to sustainability and profitability accruing from the integrated farming are as under:

- Efficient conservation and optimization of natural resources
- Productive recycling of organic wastes among different components of farming system
- Enhancement of soil health including organic carbon status and microbial activity
- Prevention/ minimization of soil erosion and other land degradation hazards
- Improvement of soil productivity capacity
- Reduction in use of external inputs and hence, less crop production cost
- Increased environmental and ecological safety
- Meeting multiple demands relating to fodder, feed, food, fibre, fertilizer, fuel, timber, medicine, etc.
- Greater employment, livelihood and nutritional opportunities
- Regular flow of higher income leading to poverty alleviation
- Insulation of farmers against risks arising from calamities, such as drought, weather aberration, pest virulence, etc.
- Security of greater self reliance among farming communities
- Ecological and biological stability of natural resources as well as of productivity

Fisheries

Fishes, being an important source of high protein, essential minerals, vitamins, aminoacids and energy, provide food and nutritional security to millions of people. They provide employment, livelihood enhancement and export trade. India accounts for one-fourth of trade in global fish market. In the year 2006 fish export was worth US$ 1.6 billion. The total fish production including inland and marine in 2003-04 was 6.4 MT being more than 8 times than that in 1950-51 (0.75 MT). Comparatively, the growth rate has been higher in the inland fisheries than in the marine fisheries. The gap between the demand and supply is increasing. The total fish requirement is estimated at about 13 MT, and hence, concerted efforts are needed to augment production. Fish contributes towards 4.5% of agricultural GDP and 1.4% of overall GDP. Aquaculture contributes towards 75% of inland fish production in India. Only about 40% of marine fish potential has been harnessed, indicating still a substantial scope, as marine fish is of significant commercial value.

Significant advances have been made in induced breeding, tissue culture, seed production, composite fish culture, pearl culture, etc. Techniques have been developed to detect infection of fatal viral diseases even before appearance of clinical symptoms. Genetic manipulations were employed to produce desirable fish traits. It is possible to produce all male or all female or all sterile for commercial advantage. Microbes have been developed to improve utilization of nutrients from industrial byproducts and to enhance N fixation in ponds with blue green algae such as azolla.

Recent application of biotechnological techniques has proved beneficial in addressing the problems facing fisheries and in accelerating fish production of desired quality. With adoption of improved technologies the farmers in Punjab and Haryana are producing carps @ 12 t $ha^{-1} yr^{-1}$. Pond productivity has increased from 200 kg $ha^{-1} yr^{-1}$ to a national average of 2200kg $ha^{-1} yr^{-1}$. The average pond productivity in Andhra Pradesh and West Bengal is more than 4 t $ha^{-1} yr^{-1}$.

Livestock

In the last couple of conferences there has been stress on the issues of conservation of native and local livestock, the important ones being Garol sheep of Sundarbans, Swamp buffalo of Sundarbans, Nicobari fowls of Andaman & Nicrobar Islands, Black Bengal goats, Gir cattle, etc. Billy, the goat breed, resident of Barren Island in the Andamans (Barren Island is home to the only active volcano in the country), has survived the valcano's eruption by migrating to the unaffected side of the island, feeding on its sparse foliage, and surviving on seawater. Generically, Billy is a feral goat-nomadic, untamed in Barren Island. Few other animals have been known to withstand the vagaries of such a harsh environment. Feral goats like Billy could be bred in "Zero management farms" that can provide enormous quantities of mutton at next to no cost. For one, the feral goat could be the answer to the livestock problems of drought affected regions, where fresh water is in short supply. Secondly, research work on its kidney, which has adapted to seawater could yield rich results (drinking saline water can kill a human being in a matter of days). But how did Billy get on with Barren Island in the first place? But if Billy is such hot property, then why isn't it world famous yet? It will be quite some time before Billy finds its way to fame, which is bound to land it up on elite dinner tables.

In addition, livestock and poultry strains of economic importance in different coastal areas should be identified and conserved. For example, improved strains of birds as backyard poultry units in tribal areas may be identified and conserved. Appropriate genetic engineering and other biotechnological tools should be utilized for developing improved breeds with specific desired characters for the region. Technological improvement and popularization of duck rearing should be given importance.

Threats to coastal ecosystem

There are dramatic declines in the overall health of different types of coastal ecosystems: coral reefs, mangroves and estuaries, as well as marshes, dunes, deltas, seagrass beds, forests, etc.

Corals are vulnerable to any activity that affects the water they live in. About 20% of coral reefs have been destroyed in the last few decades and an additional 20% or more are severely degraded, particularly in the Caribbean Sea and parts of Southeast Asia. It is estimated that fully 10 percent of the world's reefs have already been degraded "beyond recognition". Thirty percent are in critical condition and will be lost completely in 10-20 years; while another 30 percent are threatened and will disappear within 20-40 years. Only 30 percent of the world's reefs are thought to be in stable condition, while those removed from the inhabited areas or otherwise are too remote to be exploited.

In the last 50 years, as much as 85 percent of the mangroves have been lost in Thailand, the Philippines, Pakistan, Panama and Mexico. Globally, about 50 percent of mangrove forests have been lost. An estimated 35% of mangroves have been removed due to shrimp and fish aquaculture, deforestation, and freshwater diversion. In Indonesia alone, over 10,000 square kilometers of mangrove forests have been converted into brackish water ponds (called *tambaks*) for the cultivation of prawns and fish. Although some successful restoration efforts have taken place, these are not keeping pace with mangrove destruction.

Even though global information on seagrass extent and loss is extremely limited, the magnitude of loss in these ecosystems is thought to be high. In the United States, for example, over 50 percent of the historical seagrass cover has been lost from Tampa Bay, 76 percent from the Mississippi Sound, and 90 percent from Galveston Bay. These losses are partly attributed to population growth and the resulting deterioration in water quality.

The incidence of harmful algal blooms along the United States coastlines increased from 200 in the 1970s. Since 1991, these algal blooms have caused nearly $300 million in terms of fish kills, public health problems, and lost revenue from tourism. More invasive or alien species are being found in coastal areas, often disrupting the food chain and eliminating native species. Scientists estimate that on any given day, as many as 3,000 different species are carried in the ballasts of the world's ocean fleet. Scientists have identified 480 invasive species in the Mediterranean, 89 in the Baltic Sea, and 124 in Australian water.

Climatic change and its impact

Under the aegis of the United Nations Intergovernmental Panel on Climate Change (IGPCC) set up in 1988 by the World Meteorological Organization and the U.N. Environmental Programme, 2500 scientists from 130 countries discussed in detail the likely impact of the global warming in the 21st century. The estimates of CO_2 emission provided by the U.N. Framework Convention on Climate Change (UNFCC) and by the World Meteorological Organization (WMO) differ, but both indicate significant increase which is contributing to global warming. The CO_2 emission from the ships was not considered under the Kyoto agreement. Considering the greater impending threat from CO_2 emissions from shipping to the delta, International Maritime Organization (IMO) should pay attention to this aspect and develop a workable strategy for combating the problem. According to the assessment report released on April 5, 2007, the consequences will prove disastrous to humanity and environment. The potential hazards are:

- Average earth's temperature could rise from 2.5 to 4.5°C, the best estimates could be about 3°C.
- There will be more heat waves, frequent droughts and floods.
- There will be more water scarcity affecting 1.1 to 3.2 billion people.
- There will be substantial reduction in crop productivity and food shortages.
- Sea level will rise by about 50-70 cm, inundating lowlying coastal areas and causing soil salinization.
- In some of the most densely populated cities massive displacement of people might take place.
- In extreme conditions large areas will become inhabitable.
- Diseases and pests will spread extensively, especially in the tropical regions.
- Rapid melting of glaciers and snow covers will take place.
- Poor nations and marginal farmers with subsistence farming, who have low coping capacity, are likely to suffer most.
- Many species will face extinction.

The nature and magnitude of the impact will vary in different regions of the world. The coastal areas in Pacific Islands, Asian countries, Australia, New Zealand, Atlantic coast in South, and Central America will face stronger surges and sea level rise. The Great Barrier Reefs in the Australian coast will be at serious threat, and upto 88% of Asian coral reefs, which provide habitat to sea creatures, may be lost on account of increasing ocean temperature. According to another report of IGPC, about 100 million people could be flooded each year by rising sea level by 2080. Roughly 75 percent of all people living in the vulnerable areas across the world are in Asia, while poor nations like Bangladesh and small islands like Maldives will suffer more. Largest cultivated area (about 1000 km^2) in Bangladesh might suffer due to sea level rise. Sea level rise will also threaten coastal areas of Florida and major cities, such as New York, London and Tokyo. In land locked countries like India, the coastal ecosystems are at risk, though they are biologically rich and diverse, and have great economic importance. One-fourth of Indian people living in the coastal areas will be hit seriously, many villages will be submerged, huge population will be displaced, and bulk of fisherfolk will lose livelihood.

In a recent study by the London based International Institute for Environment and Urbanisation, it is reported that 634 million people living in the coastal areas situated in less than 10 meters (33 feet) above mean sea level will be affected by stronger storm surges and sea level rise.

Despite their tiny size, phytoplankton are responsible for nearly 50 percent of photosynthesis, converting atmospheric CO_2 into organic carbon as food for marine ecosystems. A study in US shows that overall productivity of oceans goes down with global warming, and hence, the need for effective action programme to tackle the problem of global warming is suggested right now to reduce the cost, as the figure will increase manifold if action is delayed. Continuous increase in ocean acidity is seriously disrupting marine ecosystems and possibly fish stocks.

Natural disasters

Coastal ecosystem being highly fragile is vulnerable to volcanic activities as witnessed in December, 2004 due to devastating *tsunami*. Increasing seismic activities were recorded in Java-Sumatra-Andaman region of South Asia, thereby indicating possibility of major disaster. Besides, more than 52 earthquakes of varying magnitude have been observed recently. Due to high intensity floods in the coastal areas of Krishna, Guntur and Prakasam districts of Andhra Pradesh in the monsoon of 2006, hundreds of families were affected, crops over 1.2 M ha were inundated, and thousands of homes destroyed in the Krishna delta.

A powerful earthquake of 8.0 magnitude and a *tsunami* with devastating waves upto 10 meters in height in some villages struck the tiny Soloman Islands on April 2, 2007, washing away villages and rendering thousands of people homeless. In view of the fears of 2004 Indian Ocean *tsunami* disaster, the beaches along Australia's east coast were closed and ferry services suspended in Sydney harbour.

A large part of the Indian subcontinent is geologically unstable and is susceptible to seismic action responsible for earthquakes near the shoreline, some triggering *tsunami*. In December, 2004 more than 2.5 lakh people were killed. The post-*tsunami* rehabilitation programme is facing difficulty due to paucity of enough land for reconstruction. Therefore, efforts are underway to develop early warning system across the world, making use of modern technology to disseminate message for any threat. The present warning system is based on Deep Ocean Assessment and Reporting of *Tsunamis* (DART), which is an effort by the Pacific Marine Environmental Laboratory of National Oceanic and Atmospheric Administration of America to develop a real time reporting of *tsunami* measurements in the deep sea.

The effectiveness of the system was tested in case of *tsunami* that hit the Indonesian coasts in January, 2007. The Indian Ocean *Tsunami* Warning System functioned well and first regional warning was transmitted to the Indonesian Meteorological and Geophysical Agency (BMG) by the United States Pacific *Tsunami* Warning Center, 19 minutes after the earthquake, but the devastation could not minimized as expected. Therefore, the warning system has to be integrated with many other aspects laying emphasis on post-warning follow-up actions for faster dissemination through mobiles, television, radio, siren, bells, telephone and internet facilities, etc. to the people at risk. This will help in reducing the magnitude of destruction substantially. A new *Tsunami* Warning Centre was established by Australia to alert Asian Pacific countries, which will be able to monitor 39 Australian and 70 international stations to save thousands of lives.

National and international initiatives

The government of India has decided to set up a *Tsunami* Early Warning System in the Indian Ocean establishment of which with capability to detect earthquakes of more than 6 m was inaugurated at Hyderabad on October 15, 2007 by the Union Minister for Science & Technology. This will take 30 minutes to analyse the seismic data following the earthquake, and attempt will be made to reduce the time to 6 or 7 minutes. The Centre has been set up by the Ministry of Earth Sciences in the Indian National Centre for Ocean Information Services (INCOIS). Two more centres of excellence are proposed to be set up for collaborating with the neighbouring countries for sharing the data.

Besides, a National Disaster Management Act 2005 has been approved, and a National Disaster Management Authority headed by the Prime Minister has been constituted. The Tamil Nadu Government has signed a memorandum of understanding with the United Nations Development Programme to extend the ongoing disaster management project to all coastal districts, thereby covering the entire coastline in the state. The focus of the programme will be to enable the local communities to cope with any disaster in the limited stages.

The Marine Products Export Development Authority (MPEDA) jointly with the Network of Aquaculture Centres in Asia Pacific (NACA), Bangkok is setting up an independent society called the National Centre for Sustainable Agriculture (NaCSA) in Andhra Pradesh. The NACA is affiliated to FAO of the United Nations and is working with MPEDA. The NaCSA will organize prawn farmers into primary aquaculture societies, and will promote sustainable and environmental friendly farming practices. Prawns are cultivated by about 0.5 million small farmers on 96000 ha with water spread area of 77,500 ha in Andhra Pradesh.

Recognizing the disastrous effects of the global warming of the earth's surface and inevitable rise of sea levels, the representatives of 165 countries met at Nairobi (Kenya) to review the situation 15 years after 1992 UN Conference on Environment and Development held in Rio de Janeiro and 9 years after the 1997 Kyoto Protocol (which came into effect in February, 2005). The serious nature of the problem was emphasized and all agreed to meet again in 2008.

- The Government of India decided to observe 2007 as Water Year to focus on water related issues like rainwater harvesting, recharging ground water, its governance in participatory mode, development of water resources and irrigation potential to accelerate agricultural growth and food security and other aspects, create massive awareness about conservation and judicious use of water. The government is also planning to set up a Flood Management Authority for facing challenges posed by floods.

Finally, I would like to suggest that this is possibly the appropriate juncture, in the wake of fast changing climatic pattern and it's apparently clear influence on coastal agriculture and livelihood system, for peoples across all boards and countries, discuss threadbare on the relevant issues for an improved and more secured living. This is a global phenomenon and the entire world has to collectively think about it for drawing holistic strategies. Though there are a number of political and domestic issues involved in the process it should be primarily for the scientists and planners to generate the appropriate input and provide the necessary feedback for a long term solution. Scientists, planners and developmental agencies have a crucial role to perform and this symposium is certainly going to be a landmark in this respect since there are representatives participating from a number of countries all over the globe.

I wish this symposium a happy deliberation and a great success.

Thank you.

J. Indian Soc. Coastal agric. Res., 26(1), 12-15, 2008

Keynote Address

Coastal Agriculture: Needs Economic Growth Using Knowledge Intensive Technology with Human Face

SWAPAN K. DATTA

Rash Behari Ghosh Professor of Botany, University of Calcutta
35 Ballygunge Circular Road, Kolkata-700 019, India
(E-mail : swpndatta@yahoo.com)

Good morning ladies and gentlemen, Hon'ble Minister of Parliamentary Affairs and Environment Sri Sailen Sarkar Mahasay, President, Indian Society of Coastal Agricultural Research (ISCAR) Dr. J.S.P. Yadavji, Secretary of the Society and Convener of this symposium, Sri H.S. Sen, Sri B.K. Bandyopadhyay, Sri Dhiman Burman, and I see many eminent and visionary scientists amongst us, like Dr. M.V. Rao, Dr. Ayyappan and many other distinguished scientists and delegates. We are happy to see several IRRI scientists with us, Dr. Ismail Abdelbagi, Dr. R.K. Singh, scholars/scientists/ workers devoted for the improvement of agriculture of coastal ecosystem, fellow colleagues, and all other dignitaries and friends from abroad and India. I welcome you all to this international symposium on "Management of Coastal Ecosystem: Technological Advancement and Livelihood Security" organized by the ISCAR.

I am deeply honoured and privileged to be here to deliver the Keynote speech with my limited knowledge on the subject. The possible reason for which I may qualify is my passion for people, ordinary people of the coastal ecosystem and my dream to move them for a better life. I am grateful to the organizers under the leadership of the President of the Society, Dr Yadavji and able Secretary, Dr. Sen for giving me this opportunity to deliver my presentation.

There is a fundamental question of the improvement of coastal livelihood. Should it only be based on agriculture: continue with its traditional outlook or integrate the interface of tech-based agriculture or find the new opportunity such as in Korea for reclamation of saline prone land for irrigated agriculture, in Japan for the new airport, or at Nayachar, Haldia for a proposed chemical hub?

I would try to elaborate a few issues in my presentation.

The livelihood of the North and South is digitally divided with the generation of wealth using modern knowledge of technology in the North, while South is burdened with millions of resource poor people with traditional knowledge but surplus with natural resources. How can we translate the natural resources in this ecosystem into sustainable growth of agriculture along with the improvement of livelihood of the people? This is the most important question before us. In general, India is a huge country with a large agricultural base. Agricultural growth rate was less than 2% in the last decade. Yield growth also declined. Land degradation, soil erosion and waterlogging have increased. Are we short of technology, which could prevent all the said disasters? The recent *tsunami* and other unpredictable natural disasters have also contributed misery to the people and damage of the coastal lands. Fortunately, scientists and policy makers are seriously concerned about the matter and some preventive measures and signaling system to monitor and predict *tsunami* type disaster are emerging. *Tsunami* alarming system will help India and neighboring countries as well.

Our biggest problems remain with the failure of generating productive employment, which is critical to reduce the poverty and hunger. Mangrove ecosystems – comprising forests as well as numerous terrestrial and aquatic species – are widespread in the Asia-Pacific coastal areas and play an important ecological role while providing a variety of services for human well being. For India, We can only hope that the recommendations of Agricultural Commission on Farmers, 11th Plan Working Groups and the Steering Committee report of the Planning Commission will reveal some of the solutions of agricultural problems attached to this fragile ecosystem.

World's coastal ecosystem, human intervention and Indian scenario

The coastal areas of India, 8129 km long, accommodate about one-fourth of country's population that is dependent largely on marine resources. Ironically, the world's marine environments are also the disposal systems for human generated waste. Although non-coastal communities also have pressing environmental issues, maintaining sustainability in coastal development is particularly important because "More than half the world's population lives within 60 km of the shoreline, and this could rise to three quarters by the year 2020" (United Nations Conference on Environment and Development [UNCED], 1992)

Let me place a few specific examples of integrated coastal management issues with an understanding of organizational and institutional interactions in this process.

Agriculture & food security

The two main reasons why livelihood and food security issues remain critical for a country like India are (1) the heavy dependence of the majority of the population on the agricultural sector for employment and as a source of income, and (2) the large number of undernourished people, the majority of whom are below the poverty line, spend a considerable proportion of their total income on food. This is high time for a change towards agri-industrialization and passing through a transition phase of adaptation of innovation for a better life.

Horticultural and plantation crops

The coastal ecosystem offers vast scope for commercial use not only for a wide variety of fruit and vegetable crops, but also plantation crops, spices and medicinal plants. Both cashew and black pepper are good foreign exchange earners. Cashew is cultivated mostly in the coastal areas. Release of improved varieties and improved production technologies for all these crops have brought significant improvements in the production of these crops.

Tropical root and tuber crops form an important group of staples serving as secondary or subsidiary food for one-fifth of world population in tropics and sub-tropics and are the third important group of food materials after cereals and pulses.

Globalization and trade liberalization have posed unprecedented challenges to Indian spices, which is the major export earning commodity. China and other neighbouring countries are taking the advantage of the opportunity of trade liberalization.

Biofuel/biodiesel is now an attractive opportunity to utilize the surplus biomass and converting them into industrial products. There is need for suitable use of technology in order to translate the biomass to energy production for a significantly high return.

Conventional breeding & genetic resource development

The future crop management lies in the evolution of better varieties through appropriate breeding strategies coupled with improved agro-input management practices for rainfed and harsh agroecological environments, viz. salinity, acidity and flood for development/identification of genotypes with higher genetic yield ceiling under irrigated and rainfed shallow lowland conditions, and consolidation of the already achieved yield gains in rainfed and irrigated ecosystems. We need improved seeds/germplasm for varietal improvement suitable for adverse ecosystem.

Earlier there was a freedom of germplasm exchange across the countries though CGIAR and other systems which provided benefit to all for varietal improvement programme. Global trade issues, conflict of interests and dominating roles of private sectors on seed/vegetable business and uncertain roles of CGIAR today have posed a different challenge we must address.

Biotechnology

Green revolution saved millions of people from hunger around the world but the advantage did not reach to the people in the unfavourable ecosystem including coastal ecoregions. Biotechnology can offer new tools for the improvement of the germplasm (crops/fisheries/livestock, etc.) which could change the economic power of the people associated with this ecosystem.

Genetically engineered salt/drought tolerant crops including rice are being developed globally as well as in India. Once they are developed and available would create great impact in changing agricultural scenario in the coastal regions as well.

Studies conducted at IRRI, Philippines and elsewhere on abiotic stress tolerance suitable to coastal ecosystem suggest a few important strategies for a better understanding of water stress tolerance in rice and develop transgenic rice to survive critical period of water stress, which includes (1) 'switching on' of transcription factor regulating the expression of several genes related to abiotic stress, (2) understanding of phenotype and GXE in a given environment, (3) selection of a few adaptive rice cultivars suitable to drought/ salinity prone areas, (4) expediting cloning and characterizing the stress induced genes through microarray, proteomics, QTL and MAS, and (5) development of transgenic rice for drought/ salinity/ high/ low temperature, etc. Also, it is possible to develop Biotech rice for higher productivity, built-in plant protection, better nitrogen and phosphorus use efficiency, Sub1 rice for submergence tolerance and nutrition improvement (pro-vitamin A rice, high iron rice, high folate rice, high lysine rice, etc.), all of which are in place. There is need for the right policy and understanding to utilize the materials for the benefit of farmers and consumers.

Issues regarding IP, TRIPS, World Bank driven and ICAR managed NAIP project, US led Initiative of Knowledge based intensive technology are only a few examples which need attention. A simple question may be asked as to why we cannot have an Indian initiative to help and improve the livelihood of an important ecosystem.

Alternate farming systems

This would provide steady income to the farmers, ensure buffer stock against risks due to crop loss or price fluctuations, and generate income during gestation period from horticulture and plantation crops. For coastal areas having rich and diverse stock of flora and fauna, the integrated farming system may combine crop production with sericulture, apiculture, dairy, poultry, aquaculture, forestry, etc. Agro-forestry, silvi-horticultural, silvi-pastoral system would come under a programme for which location specific packages need to be developed. It should be ensured at the same time that the technologies so developed are socially acceptable and economically viable. A suitable example on alternate farming package may be combining aquaculture with lowland rice.

Watershed management and rainwater conservation

Watershed management aims at an integrated use of land and water resource, on the one hand, and higher productivity and sustainability, on the other, depending upon the local conditions. It helps reduce erosion, runoff and other degradation processes, and augments availability of food, fuel, fodder and other products.

Fisheries

The Indian marine capture fisheries sector plays a significant role in the food and nutritional security, national economy, employment generation and export trade. The country exports a wide ranging array of seafood to more than 52 countries earning substantial foreign exchange.

Strategies for future: The fisheries sector contributes about Rs. 22,200 crores to the GDP, which is about 1.4 percent of the total GDP and 4 percent of the agricultural sector. The future objectives should focus in the following areas (i) to contribute to food and nutritional security, (ii) to increase contribution to GDP, (iii) to augment export earnings, (iv) to generate employment, and (v) to ensure sustainable development of the sector.

Livestock

It is well perceived that the issues of conservation of native and local livestock, the important ones being, for example, Garol sheep of Sundarbans, Swamp buffalo of Sundarbans, Nicobari fowls of Andaman & Nicrobar Islands, Black Bengal goats, Gir cattle, etc. need concerted attempts for conservation and use for higher productivity and quality improvement of products.

Mangrove forests, Geographical Information System (GIS) and coastal resources management

Today, mangrove ecosystems are valued not only for their resource (timber) value but for their "ecosystem services" in soil building, watershed stabilization, coastal protection, fish habitats and nurseries, and as habitats for organisms for rural villagers for protein resources. When valuation of all of the ecosystem services mangroves provide is accomplished, the forest left standing is more valuable than its timber alone.

Tsunami and its impact on agriculture, livestock and fisheries

Although not as frequent as in the Pacific Ocean, *tsunamis* generated in the Indian Ocean pose a great threat to all the countries of the region.

The impact of the recent *tsunami* was influenced by the differences in the topography of India's east and west coasts. Some part of the shoreline does not have any natural barriers such as mangroves or even sand dunes. The State of Tamil Nadu has developed a programme to construct a rubble mound seawall (RMS) to protect the vulnerable coastal area from sea related hazards. *Tsunami* alarm system has now been developed and works worldwide through GSM networking and mobile telephone system logged into GSM network.

Ecotourism, chemical hub in Nayachar, and 'Setusamudram'

Around the world tourism is an attractive income generation for all types of people, poor to rich business stakeholders. In developing countries, excepting a few well established ports, coastal areas, organized sea beaches, Tiger Project, and partly fisheries, most people could not take the advantage or share the benefit of tourism industry. Cuba survives well due to tourism industry while failing to attract people to work on marginal agriculture. Assuming the poor infrastructure in the Indo-Asia-Pacific coastal areas, a well managed and environmental friendly ecotourism could change the livelihood of this ecoregion. A new initiative of developing a chemical hub in Nayachar raises questions of eco-stability. Such apprehension raises questions also for 'Setusamudram', which could cause damage to the marine ecosystem. Science, management and economic viability in the long term should provide the answer. Similarly, successful development of this chemical hub could possibly change the entire region of these coastal areas in West Bengal. We need a few successful model stories of hope and development that can lead the road map of the development of the rest of the coastal areas.

Specific impacts of climate change

UNEP identifies India among the 27 countries that are most vulnerable to sea level rise. Increased CO_2 emission, high temperature, excessive agrochemical use and other anthropogenic activities caused considerable damage to the environment. Recent study also showed that CO_2 levels have increased significantly not only in the air but also in the ocean and could cause heavy damage to coastal ecosystem beyond our imagination. Sustainability of agriculture needs special attention under the global climate change. The world leaders as well as the Noble committee recognized and awarded Noble peace prize for the contributions made by the UN Committee led by Dr R.K Pachauri of TERI and Mr. Al Gore, the former Vice-President of USA on awareness of global climate change and environmental protection. This is just the recognition of the problems but actual work remains to be done.

Management

Most developing countries particularly India fails miserably in this area to utilize the natural resources, technology and on the top our own human resources. It appears that India is doing well in economics front. However, quality of life in all sectors including urban/semi-urban needs considerable improvement. Partly it is a failure of management and lack of discipline in implementing the law of order. Development of a country is not dependent on one sector, it should be an integrated approach combining all sectors sharing the wealth with proper management, using particularly well-balanced infrastructure and transport facilities connecting the countries and the people associated with the coastal ecosystem.

Finally, I would like to mention that the Indian Society of Coastal Agricultural Research has done a commendable job so far under the vibrant leadership of Dr. Yadav, Dr. Sen and tremendous contributions from colleagues and I sincerely believe that the office bearers of the society will continue to do so in future. I hope and believe that ICAR and state governments would provide necessary support and assistance as per its norms in all its future activities. I am sure that the deliberations for the next three days will be extremely useful to reach new milestones for which I urge upon you all that the activities and the recommendations thereof should be drawn objectively and in as specific terms as possible. With these words, I wish to thank the organizers for giving me this opportunity and further wish the participants a happy stay and useful interactions with a final message:

People come first and we must have the vision to ensure that the benefit goes to majority of our people to live in a sustainable and better environment.

Thank you.

J. Indian Soc. Coastal agric. Res., 26(1), 16-21, 2008

Invited Paper

Breeding Rice Varieties with Tolerance to Salt Stress

R. K. SINGH[1], GLENN B. GREGORIO[2] and A. M. ISMAIL[1]

[1]International Rice Research Institute, Philippines
and
[2]IRRI Rice Breeder for Africa, IITA, Nigeria
(E-mail : r.k.singh@cgiar.org)

Salt stress is the second largest abiotic problem affecting rice productivity, next to drought. Although there are large variations in the world wide estimates of salt affected areas, they all agree on a common message regarding the vast magnitude of the problem. Development of tolerant crop varieties which can withstand such adversity is considered to be the most viable approach economically, environmentally and socially. Since majority of such area in South and Southeast Asia falls under coastal belt or sodic soils, rice became technically the natural choice for cultivation. Salt stress is always associated with either mineral deficiencies or toxicities, thus, multiple abiotic stress tolerance must be considered while developing a suitable variety for salt affected areas.

Salt tolerance, associated stresses (Fe toxicity/deficiency, Zn deficiency, acidity and submergence tolerance), and most of the economically important traits such as yield and quality are invariably inherited quantitatively, so it is an arduous task to integrate all positive alleles for the quantitative traits in a single desired background. Fortunately rice acquired enormous variability in adaptation to most of the prevailing abiotic stresses such as salt stress. Considering this we have followed a dynamic breeding scheme for the development of salt tolerant genotypes with added tolerance to associated stresses. This is modified Diallel Selective Mating System (DSMS) involving Marker Assisted Selection (MAS) for salinity (*Saltol* locus) submergence (*Sub1* locus) tolerance, while phenotypic selection is employed for other traits.

This breeding scheme involves first and second parental series for selected donor parents and their F_1s in all the combinations. It is followed by one or two selective mating series where selected individuals are repeatedly intermated to increase the frequency of the desirable allele in the population and this continues from one cycle to another. It ensures increased parental control, otherwise it is limited to 2 – 4 parents only in self pollinated crops like rice.

The major advantages of this long term breeding strategy are to develop the genetic material for multiple abiotic stress tolerance, envisage breaking the stubborn linkage blocks in self pollinated crops like rice, forward only the desired gene frequencies to next generations, tap the reserved germplasm donors available at IRRI from different geographical niches, and also enable large scale validation and utilization of MAS for the conventional breeding strategy. The target areas for the generation of materials are envisaged as potential rice areas under salt affected soils (submergence prone coastal saline soils and inland salt affected soils), Fe toxic soils, and also Zn deficient soils for Asian and African NARES partners.

*(**Key words:** Rice, Salinity, Salt tolerance, Abiotic stress tolerance)*

World's estimates of salt affected areas range from 0.34 to 1.2 x 10^9 ha (Massoud, 1974, Ponnamperuma, 1984, Tanji, 1990, Food and Agriculture Organization database). The most economically viable, environmentally feasible and socially acceptable approach to enhance food security in the highly populated and impoverished coastal ecosystems is to use such vast magnitude of area for cultivation using tolerant crop plants as majority of such areas in South and Southeast Asia under coastal belt or in sodic soils regions, where, technically rice is the natural choice for cultivation. Salt stress seldom occurs in isolation and is always coupled with mineral deficiencies and toxicities, which compound the problem of salt stress (Ismail *et al.*, 2007). Majority of the associated soil stresses include Zn deficiency, Fe toxicity, P deficiency, and also submergence tolerance. Thus, in breeding rice for saline environments, multiple abiotic stress tolerance must be considered. Salinity tolerance, together with associated abiotic stresses, are invariably inherited quantitatively (Mishra *et al.*, 1998, Singh *et al.*, 2001). Fortunately rice has enormous variability in tolerance to most of the abiotic stresses including salinity. Despite this, vast areas of salt affected soils are either barren or have very low productivity because very little has been done to develop suitable salt tolerant cultivars.

Manifestation of salt stress in plant

Effect of the salt stress on plant depends upon the growth stage, degree of stress and environmental conditions. Soils with ECe beyond ~ 4 dS m^{-1} are considered moderately saline, while more than 8 dS m^{-1} is highly saline, for rice. Similarly, soil pH in the range of 8.8 - 9.2 is considered normal, while 9.3 – 9.7 as moderate, and 9.8 as high stress, for rice. But this too varies with the external environmental conditions. Extremely high salt stress conditions cause severe damage to plants, while the moderate to low salt stress affects the plant growth rate along with most of the growth and yield parameters, like low tillering, stunting, spikelet sterility, less florets per panicle, low 1000 grain weight and leaf scorching, etc.

Rice is considered as salt sensitive crop with the threshold of salinity as low as 3 dS m^{-1} (Maas and Hoffman, 1977). But indeed the sensitivity varies with plant growth stages. As depicted in Fig. 1, rice is relatively tolerant during germination, becomes very sensitive during early seedling stage, gains tolerance during active tillering, but becomes sensitive during panicle initiation, anthesis and fertilization, finally relatively more tolerant at maturity (Singh *et al.*, 2004, Makihara *et al.*, 1999). Thus, the seedling and reproductive stages are most vulnerable to salt stress and plants experience greater damage from salt stress mostly at these specific stages. Studies have shown that a very poor correlation exists between tolerance at seedling stage with that during reproduction, suggesting that tolerance at these two stages is regulated by a different set of genes (Moradi *et al.*, 2003). The reproductive stage is crucial as it ultimately determines the grain yield, however, the importance of the seedling stage cannot be undermined as it affects crop establishment.

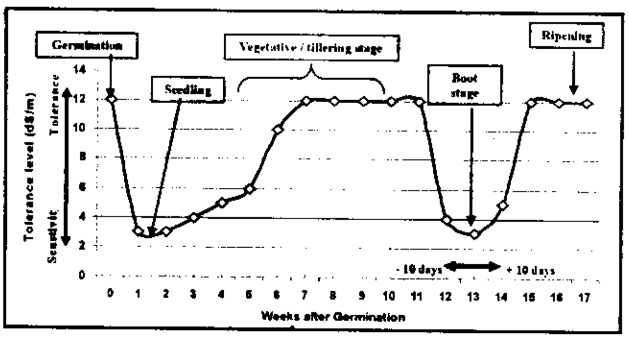

Fig. 1. Rice growth stages vs. salt tolerance

Prerequisites for the development of salt tolerant cultivars

Any breeding programme can be successful if it has two components:

- *Wide spectrum of genetic variability for the desired trait*: Fortunately rice has got a wide spectrum of variability for high salt and associated stresses.
- *Robust screening technique*: Reliable screening techniques are the backbone of any successful breeding programme specifically for breeding for biotic and abiotic stresses. Though screening techniques vary with growth stage and type of stress imposed it should ideally be rapid, reproducible, easy and affordable.

Screening methodology

- In-situ *field evaluation*: Field screening is the most ideal to identify adapted tolerant genotypes because salt tolerance is a complex phenomena, yet spatial variability in the field makes field screening less reliable. Therefore extensive field testing for soil salinity gradient and blocking with sufficient replications is the best way to minimize error chances.
- *Screening in microplots*: These are like mini-field dugout tanks filled with artificially prepared or natural soil transported from affected areas, with varying levels of desired salinity and sodicity. The results obtainrd from microplots are much more reliable than those from natural fields due to low soil heterogeneity in case of the former, which is the major bottleneck to the reliability of genotypic responses to salt stress.
- *Screening in solution culture*: Styroform with holes supported by nylon mesh are used for screening of genotypes at seedling stage. Modified Yoshida culture solution is used to supplement the solution with nutrients (Yoshida *et al.*, 1976). Four day-old germinated seeds are treated with 100 – 120 mM salinity (usually using NaCl) level to select the tolerant genotypes. IR66946-3R-178-1-1 and IR29 are usually used as tolerant and sensitive checks, respectively. Similarly perforated pots filled with fertilized soil are used for the adult plant screening and they are kept in tanks filled with the water having desired level of salinity (Gregorio *et al.*, 1997).

Screening criteria

- *Morphological parameters*: Though there is no single definite morphological marker available for salt tolerance or sensitivity in any crop, a combination of criteria can provide a good indication as to how differently crop species respond to salt stress. Therefore, several parameters are used in combination to ensure effective and reproducible screening. The most important screening parameters are seedling vigour and survival, Standard Evaluation System (SES) with scores from 1 (most tolerant) to 9 (most sensitive; IRRI, 1988), mean tolerance index, and grain yield, among other morphological parameters.

- *Physiological parameters*: Extremely high salt concentration kills the plant but moderate salt stress reflects growth differences among crop varieties due to changes in major metabolic activities. There are many physiological parameters which could be taken as the screening criteria, but the most important parameters are cation (Na^+ and K^+) uptake, Na/K ratio, and tissue tolerance. These parameters are most important because they substantially contribute to salt tolerance. Tissue tolerance is measured in terms of LC_{50}, which reflects the concentration of sodium (in mmol g^{-1} ethanol insoluble dry wt.) in the leaf tissue causing a 50% loss of chlorophyll (Yeo and Flowers, 1983).

Breeding strategy (Conventional breeding supported by MAS)

Almost all known conventional breeding methods have been used for the development of the salt tolerant varieties, i.e. introduction, selection, hybridization, mutation and shuttle breeding approaches. Most of the initial salt tolerant rice varieties, such as Damodar (CSR 1), Dasal (CSR 2), and Getu (CSR 3) were pure line selections from the local traditional cultivars prevailing in the Sundarbans areas in West Bengal, India. Initially in the mid-1970s, unsuccessful attempts were made to transfer the salinity tolerance from highly tolerant traditional varieties like Pokkali and Nona Bokra to the improved background, but the recombinants were either not equally tolerant or carried many linked undesirable traits from donors. But later in late 80's onward, and with the development of better screening techniques, many salt tolerant rice varieties in improved backgrounds were developed in different countries. Pedigree, modified bulk pedigree or shuttle breeding methods were used to develop these varieties.

Despite this progress, most of the varieties developed so far, are mostly target specific and have narrow genetic background, since the parental control is either 2 for single cross, 3 for three-way cross, and at the most 4 for double cross, a typical of self pollinating crops. To increase the parental control, broaden the genetic base and break the stubborn linkages, modified Diallel Selective Mating System (DSMS) was employed at IRRI, and a permanent breeding scheme was used for the development of the multiple abiotic stress tolerant genotypes with wide adaptability (Fig. 2). There was a little modification of the Diallel Selective Mating System (DSMS) as suggested by Jensen (1970).

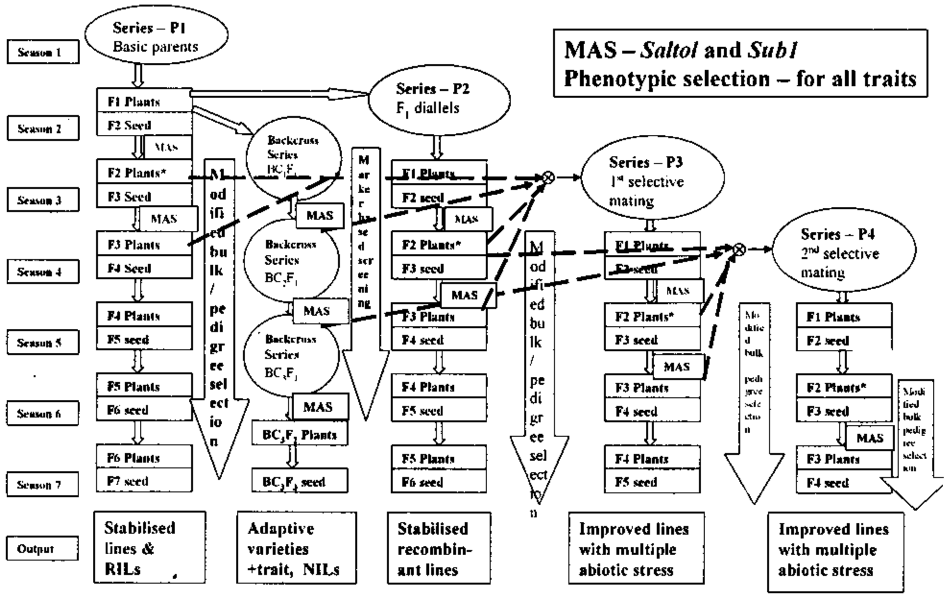

Fig. 2. Schematic diagram of the modified DSMS involving MAS

The major advantages of this long term breeding strategy are to develop the genetic material for multiple abiotic stress tolerance, envisage breaking the stubborn linkage blocks in self pollinated crops like rice, maximize the chances that only the desired gene frequencies are forwarded to subsequent generations, tap the reserved germplasm donors available at IRRI from different geographical niches, and also enable large scale validation and utilization of marker aided selection (MAS) for the conventional breeding strategy. The target areas for the generation of materials envisaged are salt affected areas (submergence prone coastal saline soils and inland salt affected soils), Fe toxic soils and also Zn deficient soils.

Rationale to follow modified DSMS

Most of the breeding programmes still consider salinity and other abiotic stress tolerance as a single trait, but indeed the tolerance or sensitive phenotype is the overall manifestations of the sum of different tolerance mechanisms operating in the genotype. Invariably the component traits responsible for stress tolerance, like Na^+ exclusion, tissue tolerance or K^+ uptake are regarded as quantitative traits. So it is a real challenge to integrate one set of quantitative traits (Na^+ exclusion and K^+ uptake) with another quantitative trait (grain yield) into a single background. In view of this, recurrent selection with intensive crossing among the selected genotypes is followed to increase the probability of getting the desired genotypes.

How to do it practically? If a trait is controlled by a single gene then the probability of getting the desired genotype would be 1 out of 4, which is the minimum perfect population. As the number of controlling genes increases, this probability declines sharply. A trait controlled by 2 genes will have the probability of 1 out of 16 to get the desired recombinant. Similarly traits governed by 5 and 10 genes would need minimum perfect population of 1024 and > 1 million, respectively, to get one desired genotype with all positive alleles. This can be illustrated using one hypothetical example. If, for example, one contributing trait, like Na^+ exclusion conferring salinity tolerance is governed by 5 genes and another trait like grain yield is governed by 10 genes, then the probability of getting the most desirable genotype with all the positive alleles at all loci would be (1/1024) x (1/1 million), which require a plant population of > 1billion, which is almost impossible to handle and identify the most desired recombinant. Due to such a low probability of desired recombinant recurrent selection is followed and the selected genotypes for one trait are crossed with selected genotypes for other traits to increase the probability of the desired recombinants that could be within one in few thousands rather than billions of plants.

As mentioned earlier, salinity always occurs with other associated stresses like Zn deficiency, Fe (toxicity or deficiency), acidity, submergence and many others. So we are using donors identified for various traits. This is a long term dynamic breeding strategy for the development of desirable plant type with multiple abiotic stress tolerance. To accommodate more diverse genotypes in the cross, partial diallel is being used in basic parent series (like 1 x 2, 2 x 3 .... n x 1). It is difficult to make many crosses in a self pollinated crop such as rice, but with the good crossing facility at IRRI, we can make half diallel without reciprocals [n x (n-1)/2]. It is a dynamic series so one cycle follows another cycle. At the moment, traits like tolerance to salinity, submergence, and Zn deficiency are being considered along with good plant type.

We have employed certain modifications in the original scheme:

- Marker Assisted Selection (MAS) is applied at F_3 generations for specific traits.
- Additional backcross series is introduced to convert the mega varieties/adapted varieties with improved tolerance to abiotic stress.
- Instead of mass selection, modified bulk pedigree method is being followed to advance the generations.

Since IRRI has standardized the MAS screening using tightly linked flanking markers for gene for submergence tolerance (*Sub1*) and salinity tolerance at seedling stage (*Saltol*), they are being routinely used for the selection of the desirable recombinants for the selective mating (Singh *et al.*, 2006). However, phenotypic selection using natural or artificial stress is employed for other traits. Work is going on for identification of genes / QTLs for Fe toxicity and Zn deficiency, and MAS will be extended to other traits like reproductive stage tolerance for salinity, Zn deficiency and Fe toxicity, once major QTLs were identified.

Recommendation strategy for the pyramiding of physiological mechanisms

The first step of the recombination strategy based on various physiological mechanisms is to group the genotypes based on the presence of predominant physiological mechanism responsible for salinity tolerance like tissue tolerance, Na^+

exclusion, K^+ uptake and Cl^- exclusion, and thereafter the genotypes with high degree of expression of the contrasting salinity tolerance mechanism are recombined for better salt tolerance. The recombinants with two or more desired traits for tolerance are screened. The recombinants are phenotyped based on the following parameters.

- Ability to withstand high concentrations of tissue Na^+ (tissue tolerant)
- Minimum per day uptake of Na^+ (more number of days for LC_{50} stage)
- High uptake of K^+ per day
- Good initial vigour
- Agronomic superiority with high yield potential

IRRI's salinity tolerance breeding programme caters the need of several NARES partner countries in Asia and Africa. Elite material, advanced bulk populations or the advanced lines generated at IRRI are distributed for site specific evaluation in target environments for better adaptability. International Network for Genetic Evaluation of Rice (INGER) platform is being used for the distribution of the germplasm to NARES through the International Rice Soil Stress Tolerance Observational Nursery (IRSSTON).

Development of molecular marker assisted selection (MAS)

Selection efficiency through conventional breeding for most of the abiotic stresses is low as most of them are controlled by polygenes and highly influenced by g x e interaction for their expression. Thus, MAS has been seen as a means of improving the speed and efficiency of conventional plant breeding because it is growth stage independent, unaffected by environment, no dominance effect, no epistasis, and very effective to use in early generations. Two important factors are needed for effective MAS strategy. First, the markers are tightly linked (1-2 cM) to loci with large effects on the trait, which is difficult or expensive or late appearing (e.g. at maturity) for accurate phenotyping. Second, linked marker alleles associated with desired alleles at target loci should consistently work across the different breeding populations. But unfortunately both of these two situations are not applicable for most traits and most populations. MAS for submergence tolerance (*Sub1* gene) in rice (Xu and Mackill, 1996, Xu *et al.*, 2006, Neeraja *et al.*, 2007) soybean c*ystx* (*rhg1*) and nematode resistance (Cregan *et al.*, 1999) are good examples where marker alleles (2 flanking marks) are consistent with desired alleles across the populations and it is difficult to phenotype.

In the salinity breeding programme at IRRI, MAS is currently being used to integrate salinity tolerance with submergence tolerance, in addition to the phenotyping for DSMS. Recombinants from crosses IR82810-407 (parent with *Sub1*) x IR66946-3R-178-1-1 (parent with *Saltol*) in F_2 and subsequent generations are genotyped for *Saltol* and *Sub1* loci together to identify the plants with both desired alleles in homozygous background. The recombinants are ~~also phenotyped to validate the MAS effectivity~~. The segregants with both loci in homozygous state are being advanced to stabilize the materials. This technology is being transferred to NARES partners for its use in their own breeding programmes because the application of MAS in national breeding programmes is the ultimate goal of IRRI.

Rice varieties developed for salt tolerance

Development of the improved salt tolerant materials directly benefits the farmers by increasing their harvest in salt affected lands. Many rice varieties were released as salt tolerant varieties in many countries. For example, Philippines has released many IRRI developed materials, like IRRI 112 as PSBRc48 (Hagonoy), IRRI 113 as PSBRc50 (Bicol), IRRI 124 as PSBRc84 (Sipocot), IRRI 125 as PSBRc86 (Matnog), IRRI 126 as PSBRc88 (Naga), and IRRI 128 as NSICRc106. In other countries also many salt tolerant rice varieties have been released for commercial cultivation like CSR10, CSR13, CSR23, CSR27, CSR30, CSR36, Lunishree, Vytilla 1, Vytilla 2, Vytilla 3, Vytilla 4, Panvel 1, Panvel 2, Sumati, Usar dhan 1, 2 & 3 (India); BRRI dhan 40, BRRI dhan 41, BRRI dhan 47 (Bangladesh); OM576, OM2717, OM2517, OM3242, AS996 (Vietnam); and Giza 177, Giza 178, Sakha 104, Sakha 111 (Egypt).

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J. Indian Soc. Coastal agric. Res., 26(1), 22-27, 2008

Application of the Contemporary Achievements in Plant Genetic Improvement for Tomato – The Basic Tool for Sustainable Development of Agriculture in the Coastal Area

ELENA BALATCHEVA[1], BISTRA TZVETKOVA ATANASSOVA[1] and P. HAZRA[2]

[1]Institute of Genetics, Prof. D. Kostov Bulgarian Academy of Sciences,
Tzarigradsko chosse 13 km, Sofia 1113, Bulgaria
(E-mail : bistra_a@yahoo.com)
and
[2]Department of Vegetable Crops, Faculty of Horticulture
Bidhan Chandra Krishi Viswavidyalaya, Mohanpur-741 252, West Bengal, India
(E-mail : hazra.pranab05@gmail.com)

For a long time, the regions in a given geographical location used to be classified as suitable for growing one or another crop, based on soil, climate, market and other factors, but progress in plant genetic improvement made possible this classification to shift to a different approach – choice of cultivar(s) suitable for a given area or even for a given farm. The aim of this paper is to present the achievements in the genetic improvement of tomato during the last five decades. Tomato (*Lycopersicon esculentum* Mill) as model crop has been chosen as it is one of the most important vegetable crops grown throughout the world occupying the third position amongst the vegetable crops after potato and sweet potato with respect to total area and total production. The transactions and references mentioned in this paper on different breeding approaches, viz. for substitution of mutant genes, development of hybrids, for delayed ripening of fruits, for enhanced fruit quality, for biotic stresses, and breeding for abiotic stresses (high temperature stress, salt tolerance) provide evidence that there have been a significant number of new trends in tomato breeding during the last few decades through genetic pyramiding of new useful traits and the modern varieties strongly differing from those grown 40-50 years ago. Such consorted breeding efforts are needed to develop ideotypes of the targeted vegetable crop suitable for coastal areas.

*(**Key words**: Tomato breeding, Mutant genes, Hybrids, Ripening period, Fruit quality, Tolerance to biotic & abiotic stress, Tolerance to heat, Salt tolerance)*

For a long time, the regions in a given geographical location used to be classified as suitable for growing one or another crop, based on soil, climate, market and other conditions, but progress in plant genetic improvement made possible this classification to shift to a different approach – choice of cultivar(s) suitable for a given area or even for a given farm. The aim of this paper is to present the achievements in the genetic improvement of tomato during the last five decades. We have chosen tomato (*Lycopersicon esculentum* Mill) as a model plant occupying the third position amongst the vegetable crops after potato and sweet potato with respect to total area and total production although it ranks top for use in the processing industries at the global level. Tomato and its products have attracted global attention because they contain different classes of antioxidants such as carotenoids (b-carotene, lycopene, etc.), ascorbic acid, phenolic compounds, α- tocopherol (Vitamin E), and different micronutrients. Several epidemiological studies indicated a beneficial effect of tomato consumption in the prevention of some major chronic diseases such as some type of cancer and cardiovascular diseases. Lycopene, the red pigment of tomato fruit, is now being considered as world's most powerful antioxidant. This transaction has been done not only to show the progress, but to point out the dissemination of information on the genetic improvement of this crop with a view to incite sustainable development of coastal areas.

Historical perspectives

Tomato gained economic importance by the end of nineteenth century or beginning of twentieth century (Rick, 1995, Peralta and Spooner, 2007). The prominent early cultivars, viz. Marglobe, Bizon, Pritchard, Break o'Day, etc., which were widely spread during the period 1900-1940, were developed through inter-varietal hybridization (Jutchenko, 1973). Great potentiality of the wild relatives of tomato for improving important characters such as resistance to biotic and abiotic stresses, fruit quality, etc. was realized in the early period of tomato breeding also, and during the early thirties a number of lines were developed by inter-specific hybridization among *L. esculentum*, *L. pimpiellifolium* and *L. cerasiforme.*

Substitution of mutant genes

The substitution of a number of mutant genes in new cultivars contributed significantly to breeding tomato varieties possessing useful new traits and adapted for different purposes. One such gene is *sp* (self prunning) that appeared as spontaneous mutation in Florida in 1914 (Rick, 1978), which controls compact, determinate habit in contrast to the usual unlimited indeterminate growth of the tomato plant. One of the greatest steps in the genetic improvement of tomato was made in the 1960's by incorporating this "*sp*" gene in the cultivar VF 145 which facilitated harvesting, particularly by machine, and the fruiting concentrated in a shorter season. It was a spectacular advancement in the history of tomato genetic improvement at the early period (Rick, 1978).

Development of hybrids

The development of hybrids was yet another important contribution to the genetic improvement of tomato during the last four decades. Studies on heterosis in tomato were initiated almost simultaneously with these in maize but tomato hybrids were introduced in practice 30-35 years later than maize hybrids. Heterosis in tomato may be expressed at any developmental stage and was observed in a large scale of quantitative traits related to plant productivity, adaptability, physiology, fruit nutritive and market quality. It is commonly known that the phenomenon was widely employed in increasing significantly early and total yield in tomato. Besides the exploitation of heterosis the development of hybrid varieties made possible incorporatation in the cultivar greater number of genes, particularly the dominant genes controlling resistance to diseases. Tomato hybrids began to take over the market at the end of sixties to the beginning of seventies, although the first commercial hybrids in some countries were developed earlier: 1942 in USA, 1932 in Bulgaria, 1938 in Japan, 1939 in The Netherlands, 1986 in France (Atanassova and Georgiev, 2007). In fact, by 1997 100% of fresh market and 80% of processing tomatoes in USA and several countries in Europe, Asia and Australia were F_1 hybrids (Duvick, 1997).

The recent advance of the molecular genetics (improving the efficiency of breeding via marker assisted selection, tagging and isolation of genes or QTL controlling a given trait, expression of these genes in transgenic plants, etc.) is expected to contribute to more efficient and extensive exploitation of heterosis in developing tomato hybrids. Combining conventional and molecular breeding techniques might offer help in reducing the time for line development, assessing heterotic groups, detecting and individually analyzing the loci underlying heterosis, and improving screening efficiency for many traits of agronomic value.

It would be important to note, as well, that the production of F_1 tomato seeds is an important potential for providing employment and improving the income of farmers. The prices of tomato hybrid seed are relatively high as hand emasculation and pollination are used for producing hybrid seed. Improving the process of hybrid seed production is one way for increasing the economic profitability for producing F_1 seeds and in this respect some successful attempts have been made during the last three decades by incorporating male sterility into hybrid breeding programs (Atanassova, 1999, Staniaszek *et al.*, 2000, Philouze, 1999, Hazra *et al.*, 2007a).

Delayed ripening of fruits

Consumers' and growers' demand and handling requirements have changed during the past two decades. Increasing yield, for example, is not any more the major focus of commercial tomato breeding programmes and even the longevity of fruit now is not appreciated if not combined with good flavour and/or texture. For this reason one of the most important goals of breeders is to develop hybrids combining prolonged longevity and good texture and flavour. Excessive softening is the main factor limiting fruit shelf life and storage in tomato and the development of cultivars possessing extended shelf life is one of the important achievements in genetic improvement of tomato during the last few decades. Fruit longevity correlates with fruit firmness, as breeders usually control longevity based on the period upto which fruits become firm after harvest (Philouze, 1995). Fruit firmness and longevity are traits of crucial importance for both processing and fresh market tomatoes which are important for growers, processors and marketers. In order to withstand the rigors of machine or hand harvesting and the transport to factory or market the fruit needs to be firm enough and much of the firmness of the early cultivars has been developed through introgression from *L. pimpinellifolium* (Scott, 1983).

Later, development of hybrids possessing fruits characterized by prolonged shelf life could be realized by incorporating in one of the parent lines the genes that control delayed fruit ripening: *rin* (*ripening inhibitor*), *alc* (*alcobaca*), *nor* (*non-ripening*). Several hybrids largely used in practice during the last twenty years indicated that hybrids heterozygous for one of the three mutant genes could produce commercially acceptable fruits with significantly longer shelf life for one to two weeks than their normal ripening parents. According to Mutschler *et al.* (1992) there were no detrimental effects of the *alc* heterozygous condition on fruit color, firmness or size.

Enhanced fruit quality

Tomato and tomato products are the major sources of lycopene in the human diet, a carotenoid compound that possesses antioxidant properties (Rao and Agarwal, 1999) and enhancement of lycopene content in fruits in the newly developed tomato hybrids and varieties becomes one of the goals of major importance for tomato breeders. Germplasm with enriched lycopene and other compounds or characteristics related to fruit nutritive and flavor quality might be developed on the basis of inter-specific hybridization (Stommel, 2001). Few genes which result in enhanced carotenoid accumulation have been identified: the *crimson/old gold* (*og*^{c}) gene increasing lycopene by about 50% while reducing β-carotene by the same amount (Scott, 1998) and the *high pigment* (*hp*) mutatant gene resulting in increased accumulation of both lycopene and β-carotene during fruit development (Myers and Chetelat, 2001).

Tolerance against biotic stress

Numerous bacterial, fungal and virus pathogens attack tomato and cause huge losses in yields. The development of cultivars possessing resistance to one or to a number of pathogens was one of the most important goals since the early stages of tomato improvement. Among the commercial varieties it was possible to determine the genetic control of resistance against fifteen pathogens and the majority of the genes controlling these resistances being dominant (Laterrot, 2000). Nowadays, the frequency of varieties resistant to *Verticillium dahliae*, *Fusarium oxysporum*. f.sp. *lycopersici*, *Alternaria alternata* f.sp. *lycopersici*, *Fulvia fulva* (*Cladosporium fulvum*), Tomato leaf curl virus and Tobacco mosaic virus are relatively high and it was possible to cumulate four to six resistance genes in the hybrids. The recent advance of the molecular genetics made it possible to use throughout the breeding process molecular markers tightly linked to resistance genes that could facilitate the development of tomato varieties with improved resistance (Yang and Francis, 2007, Scott, 2007).

Tolerance against abiotic stress

The cultivated tomato is moderately or highly sensitive to abiotic stresses such as high and low temperature, drought, salinity, excessive moisture, etc. and for this reason these stresses are considered as a serious constraint to production. The breeding of tomato cultivars tolerant to adverse climatic conditions during the different developmental stages has been conducted for long but was not always successful because of the polygenic control of the character and the stage specificity of the genes involved. Due to this breeders usually develop cultivars tolerant to a given type of stress during a specific developmental stage, (tolerant to stress at germination, tolerant to stress during the period of fruit setting, etc.).

Tolerance against heat stress

Tomatoes are grown widely in tropical and sub-tropical regions where they often experience high temperatures during fruit set. It has been well documented that heat stress can occur at mean daily temperatures of 28-29°C, which are just a few degrees above the optimum temperature range of 21-24°C. Low and medium range narrow sense heritability for flower per cluster, pollen germination, percentage of fruit set and fruits per plant under high temperatures (Hanson *et al.*, 2002, Ansary, 2006, Hazra *et al.*, 2007) implied that single plant selection in the F_2 for heat tolerance from crosses involving a heat tolerant genotype will not be effective and that selection should be based on replicated family testing in the F_3 and later generations (Hanson *et al.*, 2002). However, with a view to overwhelming importance of genetic variance for the conditioning of different fruit set characters under high temperature heterosis breeding to develop heat tolerant hybrids possessing better fruit size and quality may be the best strategy (Cheema *et al.*, 2003, Ansary, 2006). Different heat inducible gene, heat shock proteins have been identified (Liu *et al.*, 2006, Sun *et al.*, 2006) to develop transgenic tomato tolerant to high temperature stress. During the past years many breeding lines and cultivars have been developed with improved heat tolerance and the use of these hybrids resulted in dramatic increases in tomato yield in areas with high day or night temperatures during the growing season (Foolad, 2007).

Salt tolerance

Crop improvement objectives are rapidly changing to include greater production efficiencies with fewer inputs as well as expanding agricultural productivity onto marginal lands. To meet these objectives, crop cultivars which can be productive under less than optimal conditions will be required. Breeding for salt tolerance to increase agricultural production and stabilize productivity is felt increasingly important particularly in the coastal ecosystem. Plant genotypes can be developed which perform better under stress, although certain difficulties are inherent in this approach. Identification and exploitation of useful heritable variation for the developing salt tolerance in tomatoes began much later.

Soil salinity reduces plant growth and the apparent photosynthetic rate is also depressed. Shoot of the tolerant varieties shows a much higher concentration of sodium ion and proline compared with other cultivars, which may result in the maintenance of a higher turgor potential (Elwany *et al.*, 2001). Much earlier it was suggested that succulence and good selectivity of potassium over sodium are important to salt tolerance in tomato (Cuartero *et al.*, 1992). Salt stress also causes the accumulation of proteinase inhibitors and the activation of other wound related genes in tomato plants (Capiati *et al.*, 2006). Maintainence of high tissue Ca^{2+} levels and to exclude Na^{+} from the shoot are essential features underlying its adaptation to salt stress and that these features are highly heritable (Foolad, 1997).

Donors for salt tolerance in tomato were searched among the wild *Lycopersicon* species and *Lycopersicon pimpinellifolium* (PE-2) showed the best salt tolerance (Cuartero *et al.*, 1992). Other two *Lycopersicon* species, viz. *Lycopersicon peruvianum* and *L. esculentum* var. *cerasiforme* are also characterized by high frequency of salt tolerant seedlings (Rzepka-Plevnes *et al.*, 2004).

Quantitative genetic analysis of tomato response to salt or cold stress during seed germination and vegetative growth indicated that both salt and cold tolerance were complex traits, controlled by more than one gene and highly influenced by environmental variation. Molecular marker analyses indicated that at each stage of plant development salt tolerance or cold tolerance was generally controlled by the effects of a few major QTLs, which acted in concert with a number of smaller effect QTLs (Foolad, 1999). The overall results indicate that, in tomato, stress tolerance during germination is independent of stress tolerance during vegetative growth. However, simultaneous improvement of plants for stress tolerance at multiple stages of plant development should be feasible through marker assisted selection and breeding.

Transgenic tomatoes with over-expression of a single gene controlled vacuolar Na^{+}/H^{+} antiport protein, that shuttles sodium into sacs or vacuoles, inside plant cells, protecting them from salt damage, transferred from *Arabidopsis thaliana*, have exhibited a high level of salt tolerance under greenhouse conditions (Gaxiola *et al.*, 2001, Zhang and Blumwald, 2001). Although transgenic plants are yet to be examined for field salt tolerance and salt tolerant tomatoes are yet to be developed by MAS, the recent genetic advances suggest a good prospect for developing commercial cultivars of tomato with enhanced salt tolerance in near future (Foolad, 2004).

Induction of salt tolerance : High negative correlation is generally evident between fruit yield and the leaf Na^{+} or Cl^{-} concentrations. Grafting provides an alternative way to enhance salt tolerance in tomato since rootstock is able to reduce ionic stress (Estan *et al.*, 2005) which may be due to cross tolerance, the phenomenon by which a plant resistance to a stress may result in resistance to another form of stress. It has been hypothesized that LeCDPK1, a Ca^{2+}-dependent protein kinase from tomato could participate in this cross tolerance mechanism interrelating the signaling responses to wounding and salt stress (Capiati *et al.*, 2006). In another induced tolerance, application of 0.1 mM salicylic acid to tomato plants *via* root drenching provided protection against 150 mM or 200 mM NaCl stress through increased photosynthetic rates in salt stressed plants (Stevens *et al.*, 2006).

CONCLUSION

Recent concerted breeding efforts as explained above are needed to develop ideotypes suitable for the problem areas in respect of the vegetable crop like tomato in order to breakway from the traditional approaches for sustainable improvement necessary in coastal areas.

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J. Indian Soc. Coastal agric. Res., 26(1), 28-35, 2008 **Invited Paper**

Soil Organic Carbon for Maintenance of Soil Quality

BISWAPATI MANDAL, M. C. KUNDU and DIBYENDU SARKAR

Directorate of Research, Bidhan Chandra Krishi Viswavidyalaya
Kalyani - 741 235, West Bengal, India
(*E-mail : mandalbiswapati@rediffmail.com*)

Soil, a natural gift to humankind, is under stress because of demographic pressure and consequently intensive cultivation. Of the various stresses, salinity and waterlogging are of major importance in coastal agroecosystem. To alleviate it, assessment of soil quality is made marrying physical, chemical and biological attributes of soil. From a series of case studies in Indo-Gangetic plain it was found that no-fertilization (control) or cultivation only with N caused a net degradation of soil quality, whereas, integrated use of organic and inorganic sources of nutrients could aggrade the system. A few master attributes were identified for different soil types and cropping systems for assessment of their soil quality. Low organic C content is found to be one of the major causes for poor soil quality in India and cultivation with imbalanced fertilization is found to decline it further. It is proved that for sustenance of soil organic C (SOC) level (zero change due to cropping) under rice based cropping systems of the Indo-Gangetic plains of the country, a minimum quantity of 2.9 Mg C is required to be added per hectare per annum as crop residue inputs. Rice-rice system with balanced fertilization causes both a higher enrichment of SOC and also stabilization of applied C through crop residues or amendments as compared to other rice based cropping systems. Such stabilization/ conversion of crop residue C into SOC is, however, accelerated in presence of organics than in its absence. Cropping systems that leave a higher amount of C inputs through incorporation of crop residues in soils and have favourable economics may be identified and popularized for maintenance of SOC and, in turn, soil quality for sustaining crop productivity.

***(Key words:** Soil quality, Soil organic carbon, Critical C inputs, Rice based cropping system)*

Soil is a wonderful gift of nature to humankind. It performs many functions. Some are ecological, viz. i) biomass production, ii) filtering, buffering and transforming actions, and iii) providing a biological habitat and gene reserve; and others are linked to non-agricultural human activities, viz. i) as a physical medium, ii) as a source of raw materials, and iii) as a cultural heritage – palaeontological and archaeological treasures. Its well being is thus essential for societal existence. However, because of natural as well as anthropogenic reasons there is widespread degradation of soils. In India, of the total cultivated land areas of 142 million ha, about 90 million ha suffer from different forms of degradation. The extent and severity of such degradation, however, vary. Salinity and waterlogging are the two most important forms of land degradation in coastal agroecosystem.

Soils supporting good crops are again under tremendous stress because of demographic pressure and consequently intensive cultivation. Some of the stresses commonly inflicted on soil because of intensive cropping include the following (Table 1). These are ultimately manifested in declined productivity of crops even under best possible management practices and make soil "sick" to respond efficiently to fertilization and other inputs (Bandyopadhyay and Rao, 2001, Subba Rao and Mohanty, 2006).

***Table 1.** Common soil stress and related degradation processes*

Stress	Degradation processes
Heavy load due to vehicular traffic	Crusting, compacting, structural decline
Poor internal drainage, slow surface drainage, salinity, waterlogging	Soil wetness, anaerobiosis, seawater intrusion
Intensive cropping	Chemical degradation, nutrient imbalance and soil organic matter depletion
Intensive use of agrochemicals and monoculture	Biological degradation, acidification, reduction in soil biodiversity

Present soil management practices

To arrest this deterioration, we commonly recommend measures to correct deficiency of nutrients, control of pest and disease incidences, and also take steps for conservation steps including water harvesting in coastal agroecosystem. All these are done in isolation on piecemeal basis, not in a holistically or concerted manner resulting in decreasing partial factor productivity for the applied inputs. For examples, for correcting nutrient deficiency, what we do in soil testing programme, is just carrying out analysis of a very few parameters, viz. soil pH, EC, organic C, available P, available K, etc. and expect to curb the declining trend in productivity for achieving sustainable yield. But because of the complexity of the present day high input agriculture, such tests of soil for a few parameters are proved to be very much inadequate to meet the needs of the farmers and take care of health of the soil. In fact, the existing procedure for soil testing for measuring sustainable use of soil is ill developed. To address this, we need a more wholesome approach that encompasses all the soil degrading forces including salinity and waterlogging in coastal region arising out of intensive cultivation with a view to maintain the health/ quality of soil (Sharma *et al.*, 2005, Chaudhury *et al.*, 2005, Subba Rao and Mohanty, 2006, Maji *et al.*, 2004).

Soil quality

Assessment of soil quality, which is "the capacity of the soil to produce safe and nutritious food to enhance human and animal health and overcome degradative processes" is thought to be a means to this end. Soil quality has been defined by many scientists differently. Some have defined it as "fitness for use", while others as "capacity of the soil to function". However, Soil Science Society of America came up with a wholesome definition for it as "The capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality and support human health and habitation". The concept of soil quality thus includes at least four components, viz. soil productivity, environmental quality, food quality and human/animal health.

Soil quality assessment

In soil quality assessment, we consider different attributes of soil, viz. physical, chemical and biological, and also the nutritional quality of the produce grown on the soil (Fig. 1). Again, within each category of attributes, we analyse a number of parameters, namely under physical - bulk density, maximum water holding capacity, mean weight diameter, etc., similarly under chemical - pH, EC, organic carbon, available N, P and K, micronutrients, heavy metals, etc., and under biological - microbial biomass C and N, soil enzymes, mineralizable C and N, soil biodiversity, soil fauna, etc. (Maji *et al.*, 2004). These attributes are selected based on a few scientific principles, viz. i) should encompass ecosystem process, ii) should be sensitive to variations in management practices, iii) be easily measurable and reproducible, iv) should be a component of existing soil database, and v) may integrate soil physical, chemical and biological properties. Once the attributes are chosen, they are integrated into a value to assess the system as to its fitness status.

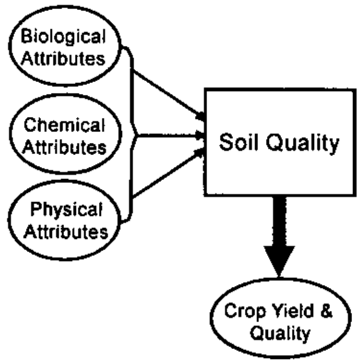

Fig. 1. A schematic framework for soil quality assessment

However to get such a value, we have to go through a rigorous screening of a few indicators from a pool of indicators and subsequently marry them together to have a unique value what we call as 'soil quality index'. Such soil quality indexing involves 3 steps: i) choosing appropriate indicators for a minimum dataset (MDS), ii) transforming indicator scores, and iii) combining the indicator scores into the index.

Case study

Through a collaborative study with 8 centres and involving 14 long term experiments under various agroclimatic zones, we could identify the following master variables (Table 2) under different cropping systems and soil types and also proved that cultivation without any fertilization (control) or only with N caused a net degradation of soil quality. Cultivation even with application of balanced NPK could hardly maintain such quality at the level where no cultivation was practised. Only integrated use of organic and inorganic sources of nutrients could aggrade the system (Table 3). To save our precious soil resource, a few of the master variables identified for different soil types and cropping systems through soil quality assessment may be included in the current soil testing programme and analyses in order to make it a robust

***Table 2**. Indicators identified for different soil types and cropping systems (Mandal, 2005)*

Soil type	Cropping system	Indicators identified
Clay loam	Rice - Rice	Zn, %BS, av. K & Dehydrogenase activity
Sandy loam	Groundnut - Redgram	MBC, pH, av. P & K, WHC & Zn
Sandy loam	Rice - Lentil	OC, av. P, Ca & Mg
Sandy	Sorghum - Castor	av. N, P, K & S, MBC & HC
Sandy loam	Jute - Rice - Wheat	av. P, MBC, MWD & OC
Sandy clay loam	Rice - Rice	Dehydrogenase activity & av. K
Silty clay loam	Rice - Field Pea	MBC, OC, av. S & P
Sandy loam	Rice - Wheat	OC, Min. N, Alk. phos, & MBC

***Table 3**. Soil quality change (as % over fallow) under different management practices and cropping systems (Mandal, 2005)*

Treatment/Cropping system	Rice-Rice	Rice-Rice	Rice-Field pea	Rice-Lentil	Jute-Rice-Wheat
Control	- 28.6	- 16.8	- 19.7	- 8.0	- 49.0
N only	- 14.0	- 14.8	- 7.1	- 11.7	- 35.0
NPK only	0.9	7.2	31.7	-9.7	19.0
NPK+FYM	35.0	24.9	51.2	8.6	45.1

one for assessing/maintaining soil quality. If required, simple, cheap and robust methods for the identified variables should also be developed for easy adoption by the soil testing laboratory.

Soil organic carbon (SOC) and soil quality

Soil organic carbon is a key attribute of soil quality irrespective of agroecosystem. It affects directly or indirectly many physical, chemical and biological properties that control soil quality and productivity, as well as, resistance to degradation and also impart resilience to the system. Globally, soil contains as much as 1550 Pg C (1.0 Pg= 1 x 10^{15} g) as SOC and 950 Pg C as soil inorganic C, together constituting about 3.3 times the size of the atmospheric pool and 4.5 times the size of the biotic pool (Lal *et al.*, 2004). Any attempt to enrich this reservoir through sequestration of atmospheric C will help to manage global warming significantly. This will also ensure global food security to a great extent since enrichment of C stock in soil is known to maintain soil, as mentioned earlier, in good health for sustainable crop production (Burman *et al.*, 2004, Majumder *et al.*, 2008) particularly in tropical and subtropical regions.

Organic carbon stock in Indian soils

India is endowed with diverse ecoregions and also soil types that vary greatly in C storing capacity. Approximately, the magnitude of such stock of C in Indian soils is 9.5 Pg of organic and 4.13 Pg of inorganic C. The variation in C stock in soil is the resultant effects of the interaction of five factors, viz. climate, landscape, texture, inputs and disturbance. Some of these factors, called SOC capacity factors, can be managed, whereas others cannot. Following universal principle organic C contents in soils of different ecoregions of the country, in general, are directly and inversely proportional to the rainfall and temperature, respectively and as such ecoregions receiving low rainfall and high temperature have low SOC. On average, SOC in coastal region is, however, relatively high because of a possible stabilizing effect of its salinity and waterlogging moisture regime for a considerable period in a year. Such stock of SOC is again influenced by soil types particularly their clay contents. A tentative estimate for SOC is made by Velayutham *et al.* (2000) for major soil types of India (Table 4). All these reporting low content of SOC in

***Table 4**. Organic carbon stock in major soil order of India (Velayutham et al., 2000)*

Soil order	0-30 cm (Pg)	0-150 cm (Pg)
Alfisols	4.22	13.54
Aridisols	7.67	20.30
Entisols	1.36	4.17
Inceptisols	4.67	15.07
Mollisols	0.12	0.50
Oxisols	0.19	0.49
Ultisols	0.14	0.34
Vertisols	2.62	8.78

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Sandy loam	Jute – Rice – Wheat	av. P, MBC, MWD & OC
Sandy clay loam	Rice – Rice	Dehydrogenase activity & av. K
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Indian soil is attributed to excessive tillage, imbalanced fertilizer use, removal of crop residues from field, severe soil degradation, and prevalence of tropical, subtropical, arid and semiarid climatic conditions in the country.

Anthropogenic activities and SOC

As indicated, anthropogenic activities have a direct effect on stock of SOC. In general, there is depletion in SOC stock in soil due to cultivation vis-à-vis undisturbed soils (Table 5). In fact, such cultivation is known to adversely affect the distribution and stability of soil aggregates and consequently reduces SOC stock in soils (Majumder *et al.*, 2008). The magnitude of the reduction in SOC on cultivation, however, varies depending upon the climatic conditions and intensity of cropping. Because of high temperature at equal intensity of cropping, the soils of tropical, subtropical, arid and semiarid regions of India are expected to be contributing more oxidative products (particularly CO_2) per unit SOC to the atmosphere vis-à-vis the soils of temperate and cooler regions of the world (Mandal *et al.*, 2008). Within India, such oxidation of SOC may be retarded in presence of high soluble salts and moisture regime in coastal agroecosystem.

***Table 5**. Depletion of soil organic carbon concentration of cultivated compared with that in undisturbed soils (Jenny and Roychaudhury, 1960, Swarup et al., 2000, Mandal et al., 2007)*

Region	SOC content (g kg^{-1})		Percent reduction
	Cultivated	Native	
Northwest India			
Indo-Gangetic Plains	4.2 ± 0.9	104 ± 3.6	59.6
Northwest Himalaya	24.3 ± 8.7	34.5 ± 11.6	29.6
Northeast India	23.2 ± 10.4	38.3 ± 23.3	39.4
East India	28.2 ± 2.1	33.1 ± 3.4	17.4
Southeast India	29.6 ± 30.1	43.7 ± 23.4	32.3
West coast	13.2 ± 8.1	18.6 ± 2.1	29.1
Deccan Plateau	7.7 ± 4.1	17.9 ± 7.6	57.0

Cropping systems and SOC

Crop species and cropping systems that are cultivated may also play an important role in maintaining SOC stock because both quantity and quality of their residues that are returned to the soils vary greatly affecting their turnover or residence time in soil (Table 6).

***Table 6**. Amount of crop residue C inputs into soils across treatments and cropping systems (Mandal et al., 2007)*

	Annual crop residue C inputs (Mg C ha^{-1} y^{-1})			
Cropping system	Treatment			
	Control	NPK	NPK + Organics	Mean
Rice-mustard-sesame	1.88	2.76	3.75	2.80
Rice-wheat-fallow	1.82	3.33	3.97	3.04
Rice-fallow-berseem	2.45	3.17	4.16	3.26
Rice-wheat-jute	2.58	5.08	6.17	4.61
Rice-fallow-rice	2.58	3.56	4.30	3.48
Mean	2.26	3.58	4.47	3.44

For sustenance of SOC level (zero change due to cropping) under rice based cropping systems of the Indo-Gangetic plains of the country, it was found that a minimum quantity of 2.9 Mg C is required to be added per hectare per annum as crop residue inputs (Fig. 2).

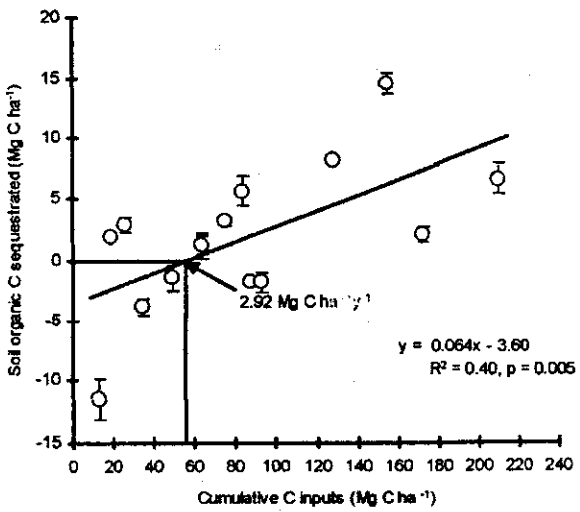

Fig. 2. Critical C input value and its influence on C sequestration (Mandal *et al.*, 2007)

Rice-rice system with balanced fertilization causes both a higher enrichment of SOC and also stabilization of applied C through amendments as compared to other rice based cropping systems. Such higher enrichment of C in the rice-rice system has been ascribed to a number of factors; of which retardation of oxidation, inclusion of extra C inputs through photosynthetic organisms and conferment of recalcitrant character to SOC under rice ecology are important. A higher content of lignin and polyphenol of crop residues of rice (Table 7) under paddy rice culture (puddling) also helps allocating SOC preferentially to passive pools of recalcitrant character with long residence time (Fig. 3). Cropping systems that leave a higher amount of C inputs through crop residues incorporated in soils and have favourable economics may be identified and popularized for maintenance of SOC and, in turn, soil quality for sustaining crop productivity.

***Table 7**. Biochemical composition (% on dry weight basis) of rice roots and stubbles vis-à-vis Lucerne and grass (Mandal et al., 2008)*

Organic residue/ Parameter	C:N	Cellulose	Lignin	Polyphenol
Rice stubble	45.4	35.0	11.0	0.56
Rice roots	58.8	21.7	16.8	0.63
Lucerne (legume)	12.1	13.6	7.3	0.32
Grass	11.2	30.0	9.0	0.25

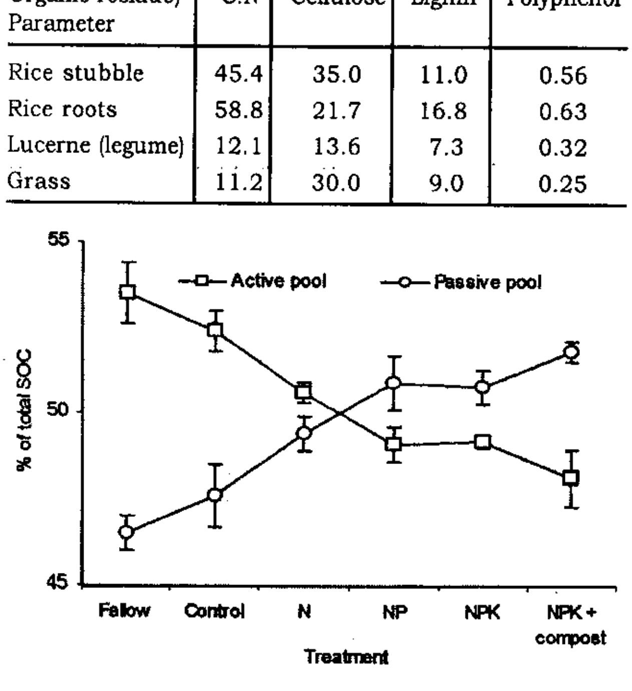

Fig. 3. Puddling and submergence help allocating SOC to passive pools (Mandal *et al.*, 2008)

Fertilization and SOC

While cultivating crops, various inputs, viz. fertilizers, organics, chemicals, water, etc. are used, mainly for increasing their economic yield with an attendant increase in the amount of crop residues, a large portion of which is returned into the soils. Intensive cultivation of crops with these inputs may thus normally be expected to result in build-up of C stock in soils. In contrast, numerous reports exist to show that C stock in soils has declined with intensive cultivation using modern inputs. For example, the soils in the Indo-Gangetic plains in India where intensive agricultural practices are followed with liberal uses of fertilizers and manures have reportedly shown declining trend of organic C content (Table 5). What is the possible reason for such decline? Is it related to imbalanced fertilization of crops? Under imbalanced fertilization practices, quantity and quality of crop residues left over in the field/ soil have been found to be inadequate to cause a desired net build-up in SOC. But soil test based balanced fertilization may cause a net enrichment of SOC (Table 8).

Organic amendments and SOC

As mentioned earlier, a declining or stagnating yield under intensively cultivated areas has been ascribed to deterioration in soil quality owing mainly to depletion in SOC. To offset such a decrease, different organic amendments such as manure (farmyard manure, green manure), compost and crop residues (particularly rice straw) are commonly recommended. Such application, however, could not cause any substantial increase (~ 10%) in SOC because of prevailing high temperature of tropical, subtropical, arid and semiarid climatic conditions of the country. When applied, a part of their C is stabilized into SOC and distributed among different pools. This process is governed by interplay of factors including climate, substrate biochemistry, C loading, soil, associated precinct, and so on. As such, the different organic amendments are likely to affect differentially the amount of C stabilized, the size and dynamics of SOC pools, and ultimately the crop productivity. In an experiment with different cropping systems, it was observed that the magnitude of stabilization of C applied through FYM was highest under rice–fallow–rice (R-F-R) (72.6 %), followed by rice–fallow–berseem (R-F-B) (33.5 %) > rice–mustard– sesame (R-M-S) (28.9 %) > rice–wheat–fallow (R-W-F) (21.1 %) = rice–wheat–jute (R-W-J) (20.1 %) (Table 9). The highest stabilization with R-F-R was possibly due to, as mentioned earlier, its unique ecology (long period of flooding/ anaerobiosis), which has a retarding effect on the oxidative loss of C.

While looking into the influence of substrate biochemistry, it was observed that 67.8, 57.3 and 49.0 % of the C applied through farmyard manure

***Table 8.** Average annual crop residue C returned to soil through above- and below-ground biomass under balanced and imbalanced fertilization for a rice-wheat-jute cropping system (Majumder et al., 2008)*

Treatment	Leaf C	Stubble biomass C	Root biomass C	Rhizode-position C	Aquatic biomass C	Annual crop residue C return to soil
			(Mg ha^{-1})			
Control	0.13	0.06	0.75	1.06	0.70	2.69
N	0.14	0.14	1.54	2.32	0.70	4.83
NP	0.16	0.17	1.85	2.74	0.70	5.62
NPK	0.20	0.17	2.11	2.97	0.70	6.15
NPK + FYM	0.25	0.19	2.37	3.18	0.70	6.68

***Table 9.** Amount of C stabilized from applied organics and crop residues (recalculated from Mandal et al., 2007)*

Cropping systems	Total C applied through organics (Mg ha^{-1})	Total C applied through organics organics (Mg ha^{-1})	Total C left over in soil from organics (Mg ha^{-1})	% of the applied C stabilized from	
				Organics	Organic + crop residues
Rice-mustard-sesame (R-M-S)	3.50	3.39	1.01	28.89	14.66
Rice-wheat-fallow (R-W-F)	9.49	2.58	2.00	21.07	16.58
Rice-fallow-berseem (R-F-B)	13.32	6.44	4.46	33.48	22.58
Rice-wheat-jute (R-W-J)	22.64	14.52	4.55	20.09	12.24
Rice-fallow-rice (R-F-R)	8.75	17.92	6.35	72.59	23.81

***Table 10.** Cumulative amount of C inputs and left over C in soils (Mg ha^{-1}) at 0-0.6 m depth after 19 years of rice-wheat cropping (Majumder et al., 2008)*

Organic amendment	C input through organics	C input through crop residues	Left over C in soil from organics		Left over C as % of the applied amount from	
			Passive pool	Total	Organics	Organics + crop residues
Farmyard manure	9.49	7.60	4.24	6.44	67.8	37.7
Paddy straw	7.98	6.08	2.38	4.57	57.3	32.5
Green manure	6.31	4.37	1.38	3.09	49.0	29.0

(FYM), paddy straw (PS) and green manure (GM), respectively, was stabilized in the form of SOC (Table 10). This shows that C applied through FYM was the most resistant while that applied through GM was the least resistant to decomposition. This is because FYM and PS have a higher C:N ratio, lignin and polyphenol content than GM (Table 11). The higher content of lignin and polyphenol in FYM and PS led to forming stable complexes with proteins of plant origin and thus made their (FYM and PS) C more resistant to decomposition than that in the GM.

Like applied organic amendments, a part of crop residue C returned to soil is also stabilized into SOC. It was observed that the rate of such conversion of crop residue C to SOC was about 1.6 times (4.2 vs. 6.9%) more in presence of organics application than in its absence suggesting that organics might have some priming effect on this conversion (Fig. 4). These results thus lead one to ponder if an extensive application of a limited amount of organics over a larger area rather than its intensive application in a smaller area would be more judicious to achieve better stabilization/ sequestration of C in soil from

***Table 11**. Composition (g kg^{-1}, on oven dry basis) of some organic amendments (Majumder et al., 2008)*

Organic amendment	Ash	Total C	Total N	C:N	Cellulose	Lignin	Polyphenol
Farmyard manure	253	333	5.0	66.6	231	175	10.8
Paddy straw	98	420	4.3	97.7	350	110	6.0
Green manure	123	414	17.0	24.3	100	89	3.2

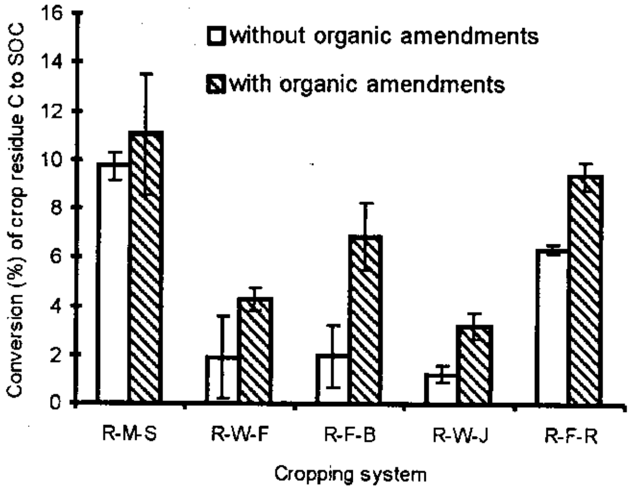

Fig. 4. Influence of organic amendments on conversion of crop residue C to SOC under different cropping systems (Mandal *et al.*, 2007).

crop residues. Such favourable priming effects of organics, their operative mechanisms and possible implications thereof, in C sequestration in soils need to be further investigated.

All the above information regarding the effects of intensive cultivation with different cropping systems and their management practices on dynamics of SOC in different agroecosystems including coastal is useful to identify the pathways of C sequestration in soils. Once identified, this may lead to evolving suitable agricultural strategies that have great potential to improve SOC stocks, thus attenuate CO_2 loading into the atmosphere, resulting in curbing of the global warming, and finally maintaining soil in good health. Some work has recently been initiated under different agroecosystems in the country in this regard. But, inspite of covering a sizable portion of land area in the country under the coastal agroecosystem, no systematic attempt has yet been undertaken to improve SOC stock. However, indications are rife that the coastal agroecosystem would be a better sink for terrestrial C compared to the others because of its unique features for occasional inundation by seawater. A major and planned initiative may be made to this end.

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J. Indian Soc. Coastal agric. Res., 26(1), 36-39, 2008

Invited Paper

Advances in Saline Water Use for Coastal Agricultural Development

S. K. GUPTA

Central Soil Salinity Research Institute, Karnal, Haryana -132 001, India
(E-mail : skgupta@cssri.ernet.in)

Coastal regions often suffer due to excess rainwater, prolonged water stagnation, high water table, high humidity and loss of nutrients in the monsoon season. Contrarily, besides drought, floods, earthquakes and cyclones that devastate the coastal regions with grim regularity, scarcity of freshwater and high salinity of soil and ground water affect crops and animal productivity in the post-monsoon season. Current scenario of soil water salinity is discussed highlighting that already precarious problems of soil/ water salinity would get aggravated due to increasing exploitation of river water upstream, increased exploitation of ground water resulting in seawater intrusion, spread of aquaculture activities along the coast, pollution due to diffuse and point sources, increased wastewater generation and its mismanagement, and impending climatic change likely to raise the sea level. Strategies to commercially use seawater or its dilutions through prawn culture, cultivation of seaweeds and establishment of multi-enterprise sea farms with components of mangrove forest, aquaculture and *salicornia* cropping have been discussed. It is observed that these activities must be scientifically planned following proper hydrological investigations to avoid or minimize the environmental degradation. For the use of medium saline/ sodic waters strategies based on crop management, irrigation water management, soil/ land management and chemical management have been illustrated from experiences of the inland as well as coastal areas. To utilize medium to high salinity water for alternate land management, qualitative and quantitative salt tolerance of forest plantations, horticultural plants, grasses and shrubs have been compiled from the literature to enable the use of salty water that cannot be put to use for arable cropping. Need to develop freshwater resources is emphasized to meet a part of the domestic, industrial and agriculture sectors demand and to facilitate conjunctive use of sea/ saline water. Towards the end, paper suggests few thrust areas of research related to salty land and water environment that needs to be initiated and/ or strengthened for sustainable coastal agricultural development and improved livelihood options for the people.

*(**Key note**:Saline water classification, Strategies for water use, Alternate land management, Crop tolerance to irrigation water salinity)*

India has a long 8129 km coastline, 0.5 million km^2 of continental shelf and 2.02 million km^2 of Exclusive Economic Zone (EEZ) adjoining the continental regions and offshore islands. The important ecosystems characterizing the Indian coast include estuaries, lagoons, mangroves, backwaters, salt marshes, rocky coasts, sandy stretches and coral reefs. Coastal regions often suffer due to excess rainwater, prolonged water stagnation, high water table, high humidity and loss of nutrients in the monsoon season. Contrarily, besides drought, floods, earthquakes and cyclones that devastate the coastal regions with grim regularity, scarcity of freshwater and high salinity of soil and ground water affect crops and animal productivity in the post-monsoon season. Salinity of land and water resources is a major constraint to increased production and productivity of coastal agriculture. While 3.0 million ha area suffer from coastal salinity, water salinity in the region varies from EC 0.7 dS m^{-1} to 3.5 dS m^{-1} for surface and 0.7 dS m^{-1} to as high as that of the seawater for ground water. Hyper-saline waters are also found in few coastal ecosystems. Current scenario of soil water salinity is discussed highlighting that already precarious problems of soil/ water salinity would get aggravated due to increasing exploitation of river water upstream, increased exploitation of ground water resulting in seawater intrusion, spread of aquaculture activities along the coast, pollution due to diffuse and point sources, increased wastewater generation and its mismanagement, and impending climatic change likely to raise the sea level. The paper highlights that the sustainability of coastal agriculture as well as all round development of the coastal regions hinge upon the integrated use of fresh, saline/ sodic and wastewaters from domestic and industrial sectors.

Categorization of water

Based on the laboratory investigations on electrical conductivity (EC), sodium adsorption ratio (SAR), residual sodium carbonate (RSC), and presence of some individual ions, such as sodium, chloride, boron, nitrate, iron, manganese, cadmium, lead, arsenic, etc. water is categorized as fresh, saline, high SAR saline, alkali and toxic. Besides, wastewaters released after first use by domestic and industrial sectors pose problems of disposal because of high BOD/ COD and microbial contaminants. In the coastal regions such waters are directly disposed off to the sea polluting this future resource of water. A thorough review of water quality in coastal India has been made to highlight the problems of various kinds of water in the coastal regions. An example from Guntur in Andhra Pradesh has been presented to reveal the dynamics of ground water quality being experienced in these regions.

Strategies to use saline/alkali water

The strategies to use saline water in coastal regions have been discussed under the three heads, namely:

- Use of highly saline or seawater (> 15 dS m^{-1})
- Use of medium saline water for arable cropping (<15 dS m^{-1})
- Alternate land management (medium/high saline water)

Use of highly saline or seawater (> 15 dS m^{-1}): Sea and its surroundings exhibit a multi-enterprise model where varied flora and fauna both sensitive and tolerant to salts are met with. If salt tolerant products could be exploited for commercial cultivation using seawater, it may open up new and lucrative livelihood options for coastal regions. Few of these options are described with examples of their application in India. Dr. M.S. Swaminathan Research Foundation (MSSRF), Chennai has developed a repository of a number of full length genes isolated from the mangrove species, *Avicennia marina* to develop and test transgenic rice varieties containing mangrove genes (Anon., 2007). To take advantage of the salt tolerance of prawns, prawn culture has been commercially adopted in coastal states and more so in Andhra Pradesh. Since important environmental issues were ignored, more than half of the area put under prawn culture in Andhra Pradesh has been abandoned causing hardship to poor farmers.

Seaweed, being the medical food of the 21st century, its cultivation is picking up fast. Seaweeds grow abundantly and naturally along the Tamil Nadu coast, inter-tidal and sub-tidal regions of Gujarat coasts, and around Lakshadweep and Andaman & Nicobar Islands. Rich seaweed beds are found around Mumbai, Ratnagiri, Goa, Karwar, Varkala, Vizhinjam and Pulicat in Tamil Nadu and Chilka in Orissa. Amongst all the cultivation methods being developed and tested at various locations, as an example, in preliminary experiments at Okha, located at the northwest coast of India, a crop yield of 22 tons (dry weight $ha^{-1}y^{-1}$) for the raft method could be achieved (Subba Rao *et al.*, 2006).

Practical applications of the concept of sea farms to bloom the deserts along the seacoast have begun (Muhawi, 2003). Within practical possibilities, the multiple enterprise system for developing sea farms consists of establishing a mangrove forest, cultivation of *salicornia* and the shrimp species *Penaeus vannamei*. Other potential halophyte is *Salvadora persica* (Gururaja Rao *et al.*, 2003). Technical and economic feasibility of extensive production of artemia, a brine shrimp for saltpans, has been established.

Use of medium saline water for arable cropping (<15 dS m^{-1}): Low to medium saline water is commonly found in inland and coastal areas. Based on extensive research work, management practices for use of saline/ alkali water have been developed and grouped under crop management, soil management, irrigation management, chemical management and rainwater management (Fig. 1).

It is important to consider important technologies/strategies developed under the above mentioned groups, notably selection of crops,

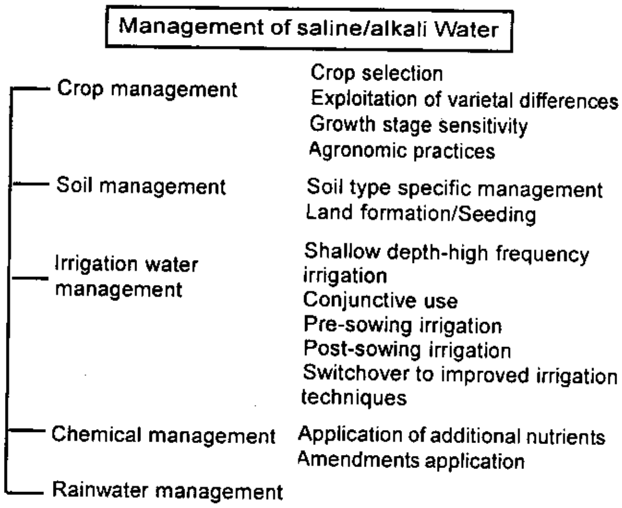

Fig. 1. Various strategies for management of saline/ sodic water

exploitation of salt tolerant crop varieties, tolerance of crops at various growth stages, and agronomic practices in the first group. In other groups, land forming and seeding techniques, pre-sowing irrigation, conjunctive use of multi-sources, multi-quality water, application of additional nutrient doses, treating waters with chemical amendments, shallow and frequent irrigations, and rainwater conservation should be included and highlighted with typical datasets (Minhas and Gupta, 1992, Gupta *et al.*, 2002). Some of these strategies require minimal investments to utilize the poor quality water in agriculture. Extension of on-farm tested agronomic practices on farmers' fields alone resulted in 5-31 % increase in pearl millet yield than the conventional practices with saline water.

Alternate land management (medium/ high saline water): In some cases, the best land use is to establish plantations. Preferred tree species for waterlogged saline soils are: *Tamarix articulata, Prosopis juliflora, Acacia nilotica, Acacia tortilis, Feronia limonia, Acacia farnesiana* and *Melia azadirach* (Tomar *et al.*, 2002). *Casuarina equisetifolia* could thrive in close proximity to the sea on loose sand, growing within a few meters of high tide level with its roots in the sea (NABARD, 1998). Besides *Casuarina, Manikara littoralis* (sea mahowa), *Terminalia catappa* (jangli badam), *Pongamia pinnata, Pandanus tectorius, Pandanus learm var. andamanensium* are suitable for erecting bio-shields along seashores (Gupta *et al.*, 2007)

The *Leucaena leucocephala* has been grown on coastal sandy soil in Pakistan, which survived when 20% seawater was used in the irrigation water, although yields were reduced by 50%. Jojoba *(Simmondsia chinensis)* is relatively salt tolerant and is being tested on coastal sand dunes at Zanjmer, Bhavnagar. Neem *(Azadirachta indica)* seedlings have been grown successfully in Pakistan on sandy soil using irrigation water with approximately 10,000 ppm salt. *Jatropha curcas*, a bio-diesel plant, is being tried to green the coastal deserts in Gujarat.

Tomar *et al.* (2003) observed that the forage grasses like *Panicum laevifolium* (3.43-4.23 t ha^{-1} y^{-1}), followed by *P. maximum* (both local wild and cultivated) out- performed the other grasses. Saline irrigation improved their productivity by 3-4 fold. The growth and forage production of *Eragrostis* species and *Aeluropus lagopoides* were good up to EC_{iw} of 40 dS m^{-1}. Gooseberry (*Emblica officinalis*), Karonda (*Carissa carandus*), Ber (*Ziziphua mauritiana*) and Bael (*Aegle marmelos*) could be grown with water salinity of EC 12 dS m^{-1}. Ultra salt affected soils can be used for growing fruit trees like datepalm, guava, ber, jamun, etc. Coconut is tolerant to salinity as well as to saline water irrigation provided saline water does not stagnate for long periods. Recently, commercial interest has been generated in mangrove palm (*Nypa fruticans)*, growing naturally in Andaman & Nicobar Islands, for alcohol production. Dagar and Singh (1994) listed tolerant trees, shrubs and grasses and forbs for saline

***Table 1**. Irrigation water salinity tolerance of some crops*

Irrigation water salinity (dS m^{-1})	Kind of crop	Crop
>20 or seawater	Forest and industrial application	*Salvadoa oleoides, Terminalia catappa, Calophyllum inophyllum,* species of *Pandanus*
14	Medicinal	*Lepidium species**, *Withania somnifera* (Ashwagandha)
12	Under-exploited species	*Cordia rothii, Azadirachta indica, Jatropha curcas, Adhatoda vasica, Ricinus communis* and *Catharanthus roseus, Plantgo ovata* (Isabgol)
10	Aromatic and medicinal	Vetiver, Palmarosa and Lemon grass
	Flowers	Calendula (*Calendula officinalis*), Chrysanthemum (*Chrysanthemum indicum*) and German Chamomile (*Matricaria chamomilla*), Periwinkle (*Chatharanthus roseus*)*
8-10	Medicinal	Egyptian henebene, *Cassia angustifolia* (Indian senna)*
	Forestry	*Acacia nilotica, A. tortilis, A. farnesiana, Azadirechta indica, Eucalyptus tereticornis, Pithecellobium dulce, Prosopis juliflora, P. cineraria, Tamarix articulata,* and *Feronia limonia*
	Grasses	*Panicum laevifolium, P. antidotale, P. virgatum, P. maximum, Cenchris ciliaris, C. setigerus,* and *Brachiaria mutica*

Compiled from Dagar (2005), * Lodha (2007) including coastal saline areas. Mango, passion fruit and pineapple are listed as sensitive while olive, pomegranate and papaya are moderately tolerant (http://www.ussl.ars.usda.gov/pls/caliche/SALTT43). In a study at CSSRI, RRS Canning, sapota has been found more tolerant to salts than guava. A compilation of crops that could be irrigated with medium to high saline waters has been made (Table 1).

Development of fresh water resources and research initiatives

Water resource management and conjunctive use of saline water in coastal/ island ecosystems can only be realized through rainwater harvesting. Some of the conventional and non-conventional techniques such as on-farm ponds, roof top rainwater harvesting, construction of check dams, skimming of fresh water lens floating on saline water, desalination of seawater, etc. could be adopted to fully utilize the rainwater potential.

Towards the end, it is stressed that in order to achieve the objective of sustainable coastal agricultural development, research initiatives related to establishment of networks on monitoring of water quality in coastal and island ecologies should receive priority. Researches on collection and preservation of germplasm of economically useful halophytes, evaluation of salt tolerance of spices, annual, biannual and semi-perennial horticultural plants for intercropping and flowering plants, breeding for salt tolerance, breeding halophytes for food quality, establishing ecological demand for water of coastal regions, construction of non-structural barriers to minimize seawater intrusion, cost reduction strategies for skimming fresh water floating on saline water, and desalination including profitable use of reject brine should be initiated.

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J. Indian Soc. Coastal agric. Res., 26(1), 40-43, 2008

Invited Paper

Dairy Farming: Prospects and Value Addition Relevant to the Coastal Ecosystem

SUSHIL KUMAR

National Dairy Research Institute, Karnal – 132 001, Haryana, India
(E-mail : dirndri@res.in)

The total milk produced by the coastal states of India is quite significant. Some of the major milk production centers of the country are located in coastal parts of Gujarat, Andhra Pradesh, and Tamil Nadu. The higher milk production in these regions may be attributed to the better animal management practices, availability of feed and fodder, efficient milk procurement and processing facilities. The scenario in coastal regions of states like West Bengal, Goa, Karnataka and all four union territories is however quite dismal. Despite having potential and huge demand of milk and milk products, dairy farming is not widely practised in these regions. The coastal regions have faced natural calamities like thunderstorms, heavy rainfall, *tsunami*, etc. in recent years that have adversely affected the agricultural activities. In such a scenario dairy farming may be an attractive option for farmers and will contribute to ensuring economic and nutritional security.

Certain region specific dairy products like *chhana* based sweets (e.g. *rasogolla* and *sandesh*) though originated in West Bengal and Orissa, have become popular throughout the country. India's total production of *chhana*, a heat and acid coagulated product, is estimated at 2 million tonnes and valued at Rs. 7000 million annually. The product is used extensively as the base and filler for the preparation of a large variety of Indian delicacies, namely *rasogolla*, *sandesh*, *cham-cham*, *rasmalai*, *pantooa*, *rajbhog* and many more such products.

Although cyclones can be predicted in coastal areas with a great degree of accuracy, cyclone disaster management means for salvaging cattle should be considered a priority by making animal shelters in such areas in safe zones to house cattle. These animal shelters could also have provision for stocking fodder, medicines and drinking water.

*(**Key words:** Dairy & dairy products, Production scenario & constraints, Milk processing scenario, Value addition, Livestock shelter, Roles of cooperatives)*

India's total coastline is about 7517 km of which 5423 km is along the mainland and 2094 km in the Andaman & Nicobar and Lakshadweep Islands. The Ganges and the Brahmaputra contribute a major share of suspended sediments to the Bay of Bengal and the Indus to the Arabian Sea. However, the oceanography of the Indian coastal region is dominated by three seasons – southwest monsoon (June to September), northeast monsoon (October to January) and fair weather period (Feb.-May). The continental shelf along the country's east coast is narrow, whereas along the west coast the width of the shelf varied from about 340 km in the north to less than about 60 km in the south. The share of milk production by cows, buffaloes and goats in the coastal states and union territories is given in Table 1. The share of coastal districts in terms of milk production is presented in Table 2.

The coastal regions are primary production and processing centers for fisheries, plantation crops, coconut and oil palm, paddy cultivation and certain horticultural crops. The region is one of the fertile and well irrigated areas of the country, especially those located across the Western and Eastern *ghats*. Animal husbandry is not widely practised as in northern states but it is a major livelihood source for medium, small and landless farmers. Organized dairy farming is rarely adopted in these regions. In states like Andhra Pradesh and Gujarat buffalo and local cattle breeds are mainly reared, whereas in Kerala, Orissa, Tamil Nadu, West Bengal and Karnataka crossbred and non-descript species outnumber buffaloes. Kerala has better animal management practices but the last two censuses witnessed a drastic decline in the livestock population leading to reduction in milk production which could be due to multiple reasons (Tables 1 & 2). The rural poverty is less in coastal regions as compared to other parts in these states most probably due to availability of number of livelihood options. However, in recent years the coastal regions have faced natural calamities like thunderstorms, heavy rainfall, *tsunami*, etc. that have adversely affected the agricultural activities. In such a scenario dairy farming may be an attractive option for farmers and will contribute to ensuring economic and nutritional security.

Milk production scenario in coastal regions

Some of the major milk production centers of the country are located in coastal parts of Gujarat, Andhra Pradesh, and Tamil Nadu. Although there has been a decline in milk production in recent years in Kerala, share of milk production of the coastal districts in the state is high (Tables 1 & 2). The higher milk production in these regions may be attributed to the better animal management practices, availability of feed and fodder, efficient milk procurement and processing facilities. In areas like Kachchh and those bordering Gulf of Khambhat animal rearing is religiously followed. In coastal Andhra Pradesh a substantial amount of milk is obtained from buffaloes, which are native of northern states and reared in organized dairy farms. Such dairy farms can serve as role model to other regions as well. The per capita availability of milk among these is highest in Gujarat followed by Andhra Pradesh and Tamil Nadu. The scenario in coastal regions of states like West Bengal, Goa, Karnataka and all four union territories is quite dismal. Despite having potential and huge demand of milk and milk products dairy farming is not widely practised in these regions. The possible reasons could be:

- Availability of other viable options like fish farming and plantation crops
- Poor performance of animals
- Widespread prevalence of diseases
- Declining acreage of fodder crops
- Poor milk procurement and processing infrastructure

Livestock shelter in coastal regions

Intense tropical storms are known in different parts of the world by different names. In the Pacific Ocean, they are called "typhoons", in the Indian Ocean they are called "cyclones", and over North Atlantic, they are called "hurricanes". Among various natural calamities, tropical cyclones are known to claim a higher share of death and destruction world over. Cyclones which occur between April and May are called pre-monsoon cyclonic storms, and between October and December – post monsoon cyclonic storms.

Table 1. *Share of milk production by cows, buffaloes & goats (2005-06) in coastal states & union territories ('000 tonnes)*

States/ UTs	Cow			Buffalo	Goat	Total	% contribution to total milk in country
	CB[a]	ND[b]	Total				
Andhra Pradesh	1051	837	1889	5735	–	7624	7.85
Goa	23	10	33	23	0	56	0.06
Gujarat	516	1742	2258	4445	257	6960	7.17
Karnataka	1489	1148	2637	1346	39	4022	4.14
Kerala	1839	108	1948	36	79	2063	2.12
Maharashtra	2420	1041	3461	3027	282	6769	6.97
Orissa	570	561	1131	208	3	1342	1.38
Tamil Nadu	3890	813	4703	771	-	5474	5.63
West Bengal	1091	2377	3469	302	121	3891	4.00
A&N Islands	5	9	14	4	2	20	0.02
Daman & Diu	0.01	0.3	0.3	0.3	0.2	1	0.001
Lakshadweep*	–	–	–	–	–	2	–
Pondicherry	39	111	41	2	–	43	0.04
							39.38%

* Breakup not available, [a]CB – Crossbred, [b]ND – Non-descript

Source: Basic Animal Husbandry Statistics 2006, Government of India, Ministry of Agriculture, Department of Animal Husbandry, Dairying and Fisheries, Krishi Bhawan, New Delhi.

Table 2. *Milk production of coastal districts of India and their share into their respective State/ U.T.*

Name of State/U.T.	Milk production for the State/ U.T. ('000 M.T.)	Milk production of coastal districts	% share of coastal district	Reference year
Kerala	2258.09	1546.08	68.27	1996-97
Maharashtra	4251.10	501.60	11.80	1993-94
Gujarat	5255.14	2669.85	50.80	1999-00
Karnataka	4784.00	389.00	8.13	2001-02
Orissa	875.13	267.00	30.50	2000-01
West Bengal	3790.00	360.00	9.50	2004-05
Andhra Pradesh	3766.00	1874.00	49.80	1993-94
Tamil Nadu	5473.62	1886.28	34.46	2005-06

Source: Indiastat.com, Dairy India yearbook 1997 (Maharasthra & A.P.)

Meteorologists have been using satellite imaging for monitoring storms for more than three decades. One of the most important applications in the endeavour is to determine the strength and intensity of a storm. Disaster warning systems have been installed in cyclone prone villages of Andhra Pradesh, Tamil Nadu, Orissa, West Bengal in the East coast. The disaster warning system disseminates warning of impending event to village administration, District Collector, State Govt. officials, etc. It has been extremely useful in mitigating cyclone disaster in the coastal states. The information has saved thousands of lives and livestock over several years in the past.

Although cyclones can be predicted with a great degree of accuracy, salvaging cattle has never been a priority. Nevertheless, cyclone disaster management means should consider making animal shelters in such areas in safe zones to house cattle. These animal shelters could also have provision for stocking fodder, medicines and drinking water. Endemic disease and chronic conditions like worm infestation or ticks require special attention. Shelter management through providing low cost shelters for protection against biotic and abiotic stresses (inclement weather, predators, etc.) including provision of green cover (trees, landscaping) should be implemented in coastal districts. It is imperative that the shelters must possess the following features:

- Provision of sheds, sanitation and hygiene, dry floors, free from drafts to reduce mastitis incidence
- Necessary health care facilities such as availability of antibiotics and vaccines for treatment of mastitis and injuries
- Deworming and spraying against ticks to improve growth and production
- Ensuring supply of clean drinking water to the livestock
- Embryonic mortality and fetal deaths would be very high in livestock if left unattended. Apart from giving adequate shelter it is important to provide them adequate green fodders/ silage/ hay along with mineral mixture not only to sustain their milk production but also to ensure prevention of embryonic and fetal losses
- Educating farmers on simple steps for maintenance of hygiene and clean milk production
- Adoption of good reproductive management practices, viz. heat detection with teasers, close observation of all open cows and buffaloes, scheduling heat detection and AI during cooler parts of the day
- Creation of storage depots for fodder and concentrates along lines of FCI
- Ensuring supply of molasses to cattle feed factories

Milk processing scenario in coastal regions of India

The milk processing scenario is on the line of milk production and all states having higher milk production also have well established milk processing and marketing networks. Like other parts of the country the majority of milk is utilized for household consumption and handled by local vendors and *halwais*. The milk is mainly converted into traditional sweets, fermented milk products and *ghee*. The strong presence of cooperatives in Gujarat, Andhra Pradesh, Tamil Nadu, Kerala and Orissa has contributed significantly towards value addition. The basic infrastructure, i.e. milk procurement, chilling, transportation, processing and marketing facilities are rather well developed. The performance of various milk federations in coastal regions is listed here (Table 3).

Few years back some private players have also entered into these regions especially in Andhra Pradesh and Tamil Nadu. The Sterling, Heritage, Hatsun Agro and Creamline Jersey are the companies that process and market milk and milk products in these two states. There is considerable scope for processing and value addition of milk in the area and the positive indicators are as follows:

Table 3. *List of important milk federations/ cooperatives and their products in coastal parts of India*

Federation/ Cooperative	Handling capacity ('000 L/day)	Processing plant	Product profile	Brand name
GCMMF Ltd.	6,595	19	Ice cream, fluid milk, *ghee*, SMP, *gulabjamun* mix, butter, *shrikhand*, *malai peda*, infant food, dairy whitener, SCM, cheeses	Amul
KCMMF	900	9	Ice cream, fluid milk, *ghee*, SMP, butter, *peda*, flavoured milk, curd	Milma
APDDCF Ltd.	2,437	12	UHT milk, flavoured milk, *ghee*, SMP, butter, *kulfi*, cheeses, *khoa*	Vijaya
KCF Ltd.	2,130	15	Ice cream, *ghee*, SMP, *gulabjamun* mix butter,*badam barfi*, *khoa*, curd, *paneer*	Nadini
TCMPF	2,700	15	Ice cream, UHT milk, *ghee*, SMP, butter, milk *peda*, yoghurt, *khoa*, dates *khoa*, *kulfi*, curd, butter milk, flavoured milk, *badam* powder	Aavin
WBCMPF	1,272	6	Ice cream, fluid milk, *ghee*, *peda*, *mishti doi*, *lassi*, flavoured milk, yoghurt, *paneer*, curd	HIMUL, Bhagirathi, Metro
OMFED, Ltd.	135	5	Pure *ghee*, butter, sweet curd, *Chennapodo*,	Omfed

Strategic locations: Most of populous cities like Chennai, Greater Mumbai, Kolkata, Kochi and Vishakapatnam are located along the coastline and there is big imbalance between the supply and demand of milk and milk products. Some of the major religious and tourist destinations like Puri, Rameshwaram, Kanyakumari, Kollam, Goa are also situated along the coastline and receive huge inflow of domestic and foreign tourists round the year. The availability of wide range of dairy products will certainly be very welcome in this regard.

Popularity of regional dairy products: Certain region specific dairy products like *chhana* based sweets (e.g. *rasogolla* and *sandesh*), though originated in West Bengal and Orissa, have become popular throughout the country. India's total production of *chhana*, a heat and acid coagulated product, is estimated at 2 million tonnes and valued at Rs. 7000 million annually. The product is used extensively as the base and filler for the preparation of a large variety of Indian delicacies, namely *rasogolla*, *sandesh*, *cham-cham*, *rasmalai*, *pantooa*, *rajbhog* and many more such products. Private sweet makers like KC Das Ltd. has made a surge in processing and marketing of *chhana* based sweets. Recently OMFED Ltd. has established a *chennapodo* manufacturing unit with the help of NDDB and marketing of this traditional delicacy of Orissa to certain parts of the country. The product is vacuum packed and has a shelf life of 15 days.

Cultured dairy products constitute a vital component of the human diet in India as in many other regions of the world. *Dahi*, *mishti doi*, *lassi*, *chhach*, *shrikhand* and many other products are essential components in people's diet in different parts of India. Besides imparting nutrition and novelty, these products have potential to alleviate diseased conditions. Around 9 % of the total milk produced in India is converted into fermented milk products and this sector is showing an annual growth rate of more than 20 % per annum. Almost all processing units manufacture *dahi* from toned milk and market it.

Value addition inherent in the manufacture of such products can be further promoted through mechanized system of production, improved packaging, and better storage and handling conditions. Convenient forms of many of these products such as instant mixes, preserved or long life formulations, etc. would also considerably help towards value enhancement especially on account of the marketing potential among urban middle class populations. Efforts leading to improved quantity and safety of these products would be valuable for both small and large scale organized productions. Export potential could be substantially materialized through the above said modified processing practices. However, it would necessitate a concerted effort to implement the developmental programmes at multi-tier locations.

J. Indian Soc. Coastal agric. Res., 26(1), 44-47, 2008 **Invited Paper**

Participatory Approach to Rice-Fish Farming in Coastal Ecosystem: Prospects and Value Addition

D. P. SINHABABU, K. R. MAHATA and SANJOY SAHA

Central Rice Research Institute, Cuttack 753 006, Orissa, India
(E-mail: sinhababucrri@rediffmail.com)

The traditional coastal-saline rice-fish culture in India is mainly characterized by: 1) wild-aqua cropping in *bheries* or *bhasabandha* in around 30,000 ha in West Bengal, 2) monocropping with traditional *pokkali* rice during wet season mostly followed by shrimp filtration in Kerala, and 3) mixed cropping of salt tolerant rice with fish and shrimp in *khazan* system in Goa. The improved rice-fish culture comprises mixed farming of salt tolerant lowland rice and freshwater fish and prawn after desalinization of field with rainwater followed by salt water fish and prawn farming. The productivity of this system ranges from 3.0-4.0 t of rice to 0.5-0.6 t ha^{-1} of fish and prawn in mixed farming during wet season and 0.4 to 0.6 t ha^{-1} of salt water fish and prawn during dry season. The value addition in rice-fish culture basically involves farm diversification with the integration of profit making components like pulses and oilseed crops, horticultural crops, prawn, livestock, fibre, fuel crops, etc. To this direction, the Central Rice Research Institute (CRRI), Cuttack has developed an easily adoptable technology of rice-fish diversified farming system for rainfed waterlogged lowlands. This system integrates different compatible components like improved rice varieties, fish, prawn, ducks, pearl culture, *Azolla*, and different remunerative crops after rice in the main field, and vegetables, fruit crops, floriculture, apiculture, mushroom cultivation, agroforestry, poultry, goatry, etc. on *bunds*. This system can annually produce about 16-18 t of food crops, 0.6 t of fish and prawn, 0.6 t of meat and 8,000-12,000 of eggs in addition to flowers, fuelwood and rice straw and other crop residues as feeds for livestock from one hectare of farm area. The system can annually generate a net income of Rs.76,000-1,30,000. This technology has been validated through farmers' participatory on-farm trials in the coastal plains of Orissa, including supercyclone affected areas. The farmers realised more than fifteen-fold increase in net farm income along with additional farm employment of 110 mandays per year. In the coastal saline ecology, integration of vegetable cultivation in the improved rice-fish farming enhanced net farm income by about 40%. Rice-fish farming has many advantages, including cost-effectiveness and ecosystem conservation, due to synergistic effect of rice, fish and other components *per se*. Moreover, this system can support multiple use of water in the coastal saline areas as it facilitates rainwater harvesting in the in-built micro-watershed-cum-fish refuge. The harvested water can also be utilized in conjunction with poor quality water. On-farm rice-fish farming practice in coastal Orissa after five years has resulted in about 50% reduction of water salinity in the micro-watershed.

***(Key words**: Rice-fish & diversified farming, Participatory approach, Technology options, Rainfed waterlogged & saline ecologies, Traditional & improved practices, Value addition, Cost-effectiveness, Resource conservation, Technology transfer)*

The total coastal areas in India are 10.78 million ha. The eastern coastal plain covering parts of West Bengal, Orissa, Andhra Pradesh and Tamil Nadu accounts for about 80% of the total area and the rest lies in the Western *Ghats* and coastal plains (Velayutham *et al.*,1999). The coastal ecosystem is characterized as low productivity (0.5-2.0 t ha^{-1}) zone of the country because rice as the major food crop is largely grown under different rainfed ecologies with multiple abiotic (salinity, drought, waterlogging, flood, cyclone), biotic (insect pests, diseases and weeds) and socioeconomic stresses. The cropping intensity in these agroecological regions is low (125-134%) since a substantial portion of the area, including 3.1 m ha salt affected areas, is monocropped with rice during wet season. Due to erratic rainfall pattern and poor water management, about 40-70% of the rainwater is lost as runoff, limiting the scope of multiple cropping/ farming. The fragility of the ecosystem and small land holdings (0.27-0.91 ha) call for diversification of the traditional rice farming for greater exploitation of rich natural resources ensuring food and livelihood security (Yadav, 2004). Rice-fish farming bears great promise in the coastal region as the available resources and the food habits of the people are highly favourable for such farming.

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Technology options

Technology options are available for rice-fish farming in various waterlogged and salt affected areas of both the east and west coast. The mixed or synchronous rice-cum-fish culture is suitable in waterlogged non-saline and low to moderately saline fields. The sequential and rotational rice-fish/prawn farming are practised in flood plains and medium to high saline areas.

Non-saline irrigated, rainfed waterlogged and saline ecologies

Rice-fish mixed culture in coastal plains has the potential of producing about 10.0 t of rice grain (two crops) and 0.2- 0.7 t ha^{-1} of fish under irrigated condition while under rainfed shallow to deepwater and non-saline to moderately saline situations, this farming system yields 2.0-5.0 t of rice and 0.3-1.2 t ha^{-1} of fish and prawn depending on the level of management. The net annual income in rice-fish farming ranges from Rs 6,895-10,781, as compared to Rs 4,037 from rice alone (Ghosh, 1992, Sinhababu and Venkateswarlu, 1998, Mishra and Mohanty, 2004). The rotational rice-fish system enhances farm income by about 72 % over the traditional farming in flood prone areas of coastal Kerala (Padmakumar, 2006). The increase in net returns from rice-fish has been reported as 50% in Bangladesh and 45-270 % in China over rice monoculture (FAO and The World Fish Center, 2004).

Coastal saline ecologies

Traditional systems: The traditional coastal-saline rice-fish culture in India is mainly characterized by: 1) wild-aqua cropping in *bheries* or *bhasabandha* in around 30,000 ha in West Bengal, 2) monocropping with traditional *pokkali* rice during wet season mostly followed by shrimp filtration in 6,400 ha in Kerala, and 3) mixed cropping of salt tolerant rice with fish and shrimp in *khazan* system in 4,800 ha in Karnataka and 1,200 ha in Goa (Bhakta, 1989). The productivity levels of rice and fish + prawn in *bheri* system are around 1.0 t ha^{-1} and 0.1-0.2 t ha^{-1} in 4 months (Jhingran and Ghosh, 1987). The productivity of fish and prawn are reported higher both in *Pokkali* (0.5-0.6 t $ha^{-1}yr^{-1}$, Natarajan and Ghosh, 1980) and *Khazan* (0.5-2.0 t ha^{-1}, Dehadrai, 1992) systems.

In Bangladesh traditional *bheri/gher* (enclosed farm area of 3.5 -50 ha having inlet and outlet with sluice gates) brackish water rice- fish/shrimp culture system is practised in south-east and south-west regions of the country with a productivity of 0.2 t shrimp and 0.1 t fish ha^{-1} (Yousuf Haroon *et al.*, 1992).

Improved systems: In modified *bhasabandha* system use of salt tolerant rice cultivars (SR 26B, CSR 1 and CSR 3) and selective stocking of brackish water fish and prawn with supplementary feeding increases productivity of both rice (2.5-3.0 t ha^{-1}) and fish and prawn (0.6-1.0 t $ha^{-1}yr^{-1}$) resulting in a higher net profit of Rs 21,755 $ha^{-1}yr^{-1}$. Similarly, modified *pokkali* system with improved management like desalinization of fields and selective stocking of mainly salt water prawn can considerably enhance the yield of rice (0.7-2.7 t ha^{-1}) and prawn and fish (0.8-2.1 t $ha^{-1}yr^{-1}$) with increased net profit of Rs 39,150 $ha^{-1}yr^{-1}$ (Ghosh,1992).

The improved rice-fish culture in coastal saline ecology of the country comprises mixed farming of salt tolerant lowland rice and freshwater fish and prawn after proper desalinization of field with rainwater followed by salt water fish and prawn farming during the dry season. The productivity of this system ranges from 3.0-4.0 t of rice and 0.5-0.6 t $ha^{-1}$of fish and prawn in mixed farming during wet season and 0.4-0.6 t ha^{-1} of salt water fish and prawn during dry season. The net income in rice-fish farming ranges from Rs 8,000- 23,000 $ha^{-1}yr^{-1}$ compared to Rs 5,100 in the case of rice (wet season crop) alone. The income further increases to about Rs 32,950 ha^{-1} with the integration of vegetable crops during wet season (Ghosh and Chattopadhyay, 1986, Biswas *et al.*, 1990, Ghosh, 1992).

In Bangladesh, the improved rice-fish farming in coastal areas involves selective stocking of fish and shrimp, use of fertilizers and supplementary feeding, and maintenance of fish and prawn nursery. During the wet season freshwater fishes are grown concurrently with transplanted *aman* rice after a preceding crop of fish/shrimp during December–March/ April. In the areas with low tidal amplitude and salinity, *boro* rice is produced during November-April, followed by fish/shrimp culture during July-October/ November. The combined yield of fish and shrimp varies from 0.3-0.5 t ha^{-1} (Yousuf Haroon *et al.*, 1992).

Value addition in rice-fish system: The value addition in rice-fish culture basically involves farm diversification with the integration of profit making components like pulses and oilseed crops, horticultural crops, prawn, livestock, fibre and fuel crops, etc. To this direction, the Central Rice Research Institute (CRRI), Cuttack has developed an easily adoptable technology of rice-fish diversified farming system for rainfed waterlogged lowlands.

This system integrates compatible components like improved rice varieties, fish, prawn, ducks, pearl culture, *azolla*, and different remunerative crops after rice in the main field, and vegetables, fruit crops, floriculture, apiculture, mushroom, agroforestry, poultry, goatry, etc. on *bunds*. In one hectare of farm area this system can annually produce about 16-18 t of food crops, 0.6 t of fish and prawn, 0.6 t of meat and 8,000-12,000 of eggs in addition to flowers, fuelwood, rice straw and other crop residues as feeds for livestock. It can annually generate a net income of Rs. 40,000- 1,30,000 depending on the level and type of component integration and their management (Sinhababu, 2001, Sinhababu and Das, 2004, Sinhababu, 2005).

Farmers' participatory on-farm trials: On-farm trials in 35 coastal saline farms in West Bengal revealed a production level of 0.8t $ha^{-1}yr^{-1}$ of brackish water fish and prawn and 2.7 t ha^{-1} of wet season rice (Ghosh,1992). Farmer' participatory trials on fish farming in modified rice fields in two districts of coastal West Bengal indicated its suitability since the yield and economic advantages were realized by the farmers (Sarkar, 1993).

The value added rice-fish diversified farming system technology has been validated through farmers' participatory on-farm trials in the coastal plains of Orissa, including supercyclone affected areas. The farmers realised more than fifteen-fold increase in net farm income along with additional farm employment of 110 mandays per year (Sinhababu *et al.*, 2006). The benefits realized by the farmers in this system have resulted in adoption of this system by farmers in other coastal areas of the state.

Benefits of rice-fish farming

Rice-fish farming has many advantages, including cost-effectiveness and ecosystem conservation, and increase in rice biomass yield by 5-15 % due to synergistic effect of rice, fish and other components *per se* (Sinhababu and Venkateswarlu, 1998). Moreover, this system can support multiple use of water in the coastal saline areas as it facilitates rainwater harvesting in the in-built micro-watershed-cum-fish refuge. The harvested water can also be utilized in conjunction with poor quality water. On-farm rice-fish farming practice in coastal Orissa has resulted in about 50% reduction of water salinity in the fish refuge/ micro-watershed after five years (Table 1).

Table 1. *Change of water salinity level during dry season in coastal rice-fish farms of Orissa*

Year	Water salinity (EC, dS m^{-1})	
	Range	Mean
2002-03	3.8-11.7	6.44
2003-04	3.4- 7.9	4.90
2004-05	1.7- 6.8	3.90
2005-06	2.2- 6.9	3. 98
2006-07	1.2- 6.2	3.11

Future strategies

Technology development

- Refinement of the available rice-fish technologies, including upscaling/ downscaling in farmer participatory mode is needed.
- Location specific suitable rice-fish farming system models are to be developed and validated for both east and west coasts of the country. These models should ensure cost-effective and environment friendly production systems with optimum utilization of natural and human resources.
- Socioeconomic studies on rice- fish farming, including marketing are to be taken up.

Technology transfer

Large scale dissemination of the rice-fish farming technologies will involve survey and characterization of the potential areas with conventional and advanced tools (GIS) followed by farmers' participatory multi-locational trials. Farmer-extension personnel-scientist partnership is necessary for location specific refinement and effective adoption of the rice-fish systems. The stakeholders should also have access to modern knowledge development and sharing tools like Information and Communication Technology (ICT) for deriving maximum benefits.Dissemination of rice-fish systems necessitates support facilities in terms of training, market intelligence and micro-finance. Linkage with the state extension personnel, ATMA, NGO's, farmers' groups, marketing agencies will strengthen adoption of the technologies.

CONCLUSION

Rice-fish farming is presently practised in only a small part of the vast potential coastal areas of the country. Adoption of the rice-fish farming system will greatly improve the production systems in under-utilized coastal ecologies.Such endeavour can considerably ensure food, nutrition, economic and employment security of the coastal framers, especially the small and marginal groups.

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J. Indian Soc. Coastal agric. Res., 26(1), 48-54, 2008 Invited Paper

Application of Biotechnological Tools for Insect Pest Resistance in Improving Rice Productivity

M. P. PANDEY, L. BEHERA, S. C. SAHU, J. N. REDDY, G. J. N. RAO and P. SEN

Central Rice Research Institute, Cuttack-753 006, Orissa, India
(E-mail: matappandey@rediffmail.com, l_behera@yahoo.com)

Various biotechnological tools have been used at Central Rice Research Institute, Cuttack to enhance the pest resistance in rice and minimize yield losses. The resistance genes for bacterial blight and yellow stem borer have been transferred into high yielding varieties from wild rice. DNA markers linked to gall midge resistance genes, viz. *Gm4* in PTB 10, *Gm5* in ARC5984 and root knot nematode resistance genes in Ramakrishna were identified.Three bacterial blight resistance genes (*xa 5, xa13* and *Xa21*) and two blast resistance genes (*Pi-2t* and *Pi-9t*) were introduced into high yielding varieties through molecular breeding approach. Different isolates of bacterial blight and blast pathogens collected from different cultivars were fingerprinted and some isolates were pathotyped using host differentials. Five populations of root knot nematode from Tiruchinapalli (Tamil Nadu), Amana, Kamakhyanagar and Cuttack (all in Orissa) were fingerprinted using RAPD markers. Potato trypsin inhibitor gene ((PIN II) was introduced to elite *indica* cultivars, viz. Swarna and Pusa Basmati 1. Two transgenic lines each from Pusa Basmati 1 and Swarna showed higher level of resistance to yellow stem borer and leaf folder. *Wolbachia*, an endosymbiotic, obligate and α-proteobacteria infection were reported for the first time from India in white backed planthopper, and leaf folder and case worm. The functional genomic tools have been applied to identify genes associated with resistance to brown plant hopper.

***(Key words:** DNA fingerprinting, Functional genomics, Marker assisted selection breeding, Molecular tagging, Transgenics)*

Rice is the most important food crop for more than a half of the world's population. In India, rice accounts for 30-50% of agricultural income and is a staple food for more than 65% of the population. With continued population growth, limited land and water resources, urbanization, post-harvest losses and possible adverse effects from climatic changes, etc. there is pressing demand to increase the productivity of rice crop on sustainable basis. The insect pests cause millions of dollars worth of losses annually to rice crop. Recent advances in biotechnology particularly in cell and tissue culture, molecular biology and functional genomics provide innovative tools for enhancing resistance against insect pests and stabilizing rice yield. Keeping pace with the developments in rice biotechnology, various biotechnological tools have been used at Central Rice Research Institute, Cuttack to enhance the pest resistance in rice and minimize yield losses.

MATERIALS AND METHODS

Wide hybridization

With an objective of transferring alien gene resistance to bacterial blight and yellow stem borer into elite cultivated rice cltivars, wide crosses were made between wild species (viz. *O. officinalis, O. longistaminata* and *O. brachyantha)* and elite cultivars of cultivated rice species (*O. sativa).* Interspecific F_1 hybrids were successfully developed by rescuing fertilized immature embryos (10-14 day-old) in 1/4th MS medium and supplemented with IAA (0.5 mgl^{-1}) and kinetin (1.0 mgl^{-1}). The resistant F_1 hybrids were backcrossed with recurrent parents for development of backcross lines with higher fertility. In order to enhance the fertility of the resistant F_1 hybrids derived from *O. sativa* (cv. Ratna)/*O. officinalis*, somaclones were developed by culturing panicle primordia (1.0 and 1.5 cm length) of F_1 interspecific hybrids in MS medium supplemented with 2,4-D (2.0 mgl^{-1}) and kinetin (1.0 mgl^{-1}). The somaclones were backcrossed with recurrent parents for development of backcross lines with higher fertility.

The interspecific hybrids of *O. sativa* cv. Jaya, Swarnaprava and *O. longistaminata* were evaluated against bacterial blight. Resistant lines were further evaluated for yield. Similarly, the interspecific hybrids of *O. sativa* (cv. Ratna, Jaya) and *O. officinalis*; *O. sativa* (cv. Savitri) and *O. brachyantha* were evaluated against yellow stem borer.

Development of molecular markers for insect pest resistance

In order to identify molecular markers linked to gall midge resistance genes in PTB10 and ARC5984, and root knot nematode resistance genes in Ramakrishna, recombinant inbred lines (RILs) were developed from the crosses between PTB10, ARC 5984 (resistant to gall midge) and TN1 (susceptible to gall midge), Ramakrishna (resistant to root knot nematode) and Annapurna (susceptible to root knot nematode) following single seed descent method. RILs (F_9) developed from the above crosses were phenotyped under artificial conditions.

The genomic DNAs of homozygous resistant and susceptible RILs of the cross TN1/PTB10 were screened with rice 47 microsatellite primers distributed on chromosome 8 while genomic DNAs of homozygous resistant and susceptible RILs of the cross TN1/ ARC5984 and Annapurna/ Ramakrishna were screened with 120 RAPD primers following bulked segregant analysis. Co-segregation analysis of phenotype specific markers was carried out on individual RILs in order to confirm the linkage between polymorphic fragments and resistance genes. Linkage between polymorphic markers and resistance genes was determined using MAPMAKER 3.0 and the genetic distance was calculated by the Kosambi function. In order to know the applicability of linked RAPD markers, viz. $OPH8_{825}$ and $OPO7_{825}$ in marker assisted (MAS) breeding programmes, the genomes of root knot nematode resistant donors, viz. Tadukan, Tetep, Zenith, TKM6 and Ramakrishna along with susceptible elite cultivar, Annapurna were amplified with RAPD primers, OPH8 and OPO7.

Marker assisted selection breeding

An attempt was made to develop durable resistant elite cultivars against major biotic stresses, viz. bacterial blight (BB) and blast by pyramiding three BB resistance genes (*xa 5*, *xa13* and *Xa21*) and two blast resistance genes (*Pi-2t* and *Pi-9t*) into high yielding varieties, viz. Swarna, IR64, Vandana and Kalinga III (Table 1). The marker assisted backcrossing was continued till BC_4F_1 with all three BB or two blast resistance gene combinations. Using the gene linked STS markers, BC_4F_2 plants possessing different gene combinations in homozygous conditions were identified and advanced for further testing.

The field performance of gene pyramided lines generated in the background of IR 64 carrying one, two or three bacterial blight resistance genes was evaluated at 11 locations in India under AICRIP trials during the wet season, 2003. Twenty genes pyramided in the background of Swarna were evaluated under AICRIP trials during the wet season, 2005 for disease reaction. Further, these pyramided lines were evaluated for grain yield and other characters during dry season, 2004. The gene pyramided lines in the background of Kalinga III and Vandana were evaluated for blast disease resistance at CRRI, Cuttack during dry season, 2006.

Molecular characterization of genetic variability in pathogen and insect populations

Four hundred-fifty isolates of *X. oryzae* pv. *oryzae* collected from different susceptible cultivars and land races in three regions in eastern India, 289 rice bacterial blight pathogen (*X. oryzae* pv. *oryzae*) isolates mostly from several cultivars grown in disease trap nursery and from experimental fields of CRRI, and 33 isolates from the states of Andhra Pradesh, Punjab and Tamil Nadu in different seasons were characterized employing PCR based DNA fingerprinting techniques. Some of these isolates were pathotyped using host differentials, carrying single resistance gene.

Eighty-five isolates of blast fungus (*P. grisea*) collected from several cultivars grown in different locations of Chhattisgarh, Sikkim and Orissa were characterized employing PCR based DNA fingerprinting techniques.

Four populations of the root knot nematode were collected from Tiruchinapalli (Tamil Nadu) and from Amana, Kamakhyanagar and CRRI farm of

Table 1. *Marker assisted selection programme for incorporating bacterial blight and blast resistance genes into rice cultivars*

Biotic/abiotic stress	Resistance gene	Donor genotype	Linked marker	Recurrent Parent
Bacterial leaf blight	*Xa4, xa5, xa13, Xa21*	IRBB60	RG136, RG556, pTA248, Xa21	Swarna, IR64,
Blast	*Pi 2t* *Pi 9t*	C101A51 WHD-1S-75-1-127	RG64 P28, RG16	Vandana, Kalinga III

Cuttack (all from Orissa), and were characterized employing PCR based RAPD fingerprinting technique.

Development of transgenic rice

Two well adapted *indica* rice genotypes, viz. Swarna and Pusa Basmati 1 were used for development of transgenic rices using hyper-virulent *Agrobacterium* LBA4404 harbouring binary vector (pRAO1). Four week-old callus derived from the mature dehusked rice grains was co-cultured with 1.0 OD culture of LBA4404 for 15 min followed by 3 days of co-cultivation on MS medium supplemented with acetosyringone. The transient GUS histochemical assay was carried out to assess GUS expression. The callii were transferred to selection medium containing hygromycin and cefotaxime. After four cycles of selection, the callii were placed on regeneration media. The regenerated plants were analyzed by GUS assay and PCR amplification. The transgenic lines of Pusa Basmati1 and Swarna containing PIN II gene were screened against yellow stem borer and leaf folder.

Molecular characterization of *Wolbachia*

Genomic DNA from 10 rice insects, viz. gall midge, brown planthopper, white backed planthopper, leaffolder, caseworm, yellow stem borer, green leafhopper, riceskipper, mealybug, stinkbug and mosquito were PCR amplified with *Wolbachia* specific primers, viz. 16S rRNA gene in order to detect the presence of *Wolbachia*.

In order to know the role of *Wolbachia* in gall midge, single male and female were allowed to mate and lay eggs on filter paper soaked with tetracycline (water, 0.01%, 0.025% or 0.05%). The larvae hatched out from eggs were transferred to rice plants. The adult emerged from inoculated plants were allowed to mate with each other (control insects or tetracycline treated insects) and lay eggs on rice plants. The genomic DNA was isolated from fertile eggs, larvae and adult insects (parents and progenies). PCR amplification of genomic DNAs was done with *Wolbachia* specific primers, viz. 16S rRNA gene. The amplification pattern was recorded.

Functional genomics of BPH resistance

Mapping populations from the crosses between susceptible cultivar, TN1 and resistant cultivars (Salkathi and Dhobanambari) were developed. F_3 lines of the cross TN1/Salkathi were screened against brown planthopper.

Genomes of susceptible cultivars, viz. Swarna and TN1, and resistant cultivars, viz. Dhobanumbari and Salkathi were screened for polymorphism with rice microsatellite specific primers distributed at a distance of 10 cM on all the 12 chromosomes. Individual F_3 lines were genotyped with polymorphic markers. Regression analysis was done to identify markers linked to QTLs associated with BPH resistance.

RESULTS AND DISCUSSION

Wide hybridization

All the interspecific hybrids were observed to be completely sterile. Out of 102 introgression lines of *O. sativa* cv. Jaya and Swarnaprava, and *O. longistaminata*, seventeen were found resistant while ten were found moderately resistant to BB. Two bacterial blight resistant promising lines, viz. CR 2212-64 and CR 2212-72 with good grain quality and yield (3.0 – 4.0 t ha^{-1}) were identified (Fig. 1).

Inter-specific back cross hybrid derivatives of *O. sativa*/*O. longistaminata* resistant to BB with slender grains

Inter-specific back cross hybrid derivatives of *O. sativa*/*O. longistaminata* resistant to BB with slender grains

Fig. 1. Promising lines, CR 2212-64 and CR 2212-72 with good grain quality and resistance to bacterial blight

Table 2. *Reaction of BC_1F_1 of* O. sativa *cv.* Savitri/O. brachyantha and *somaclones of* O. sativa *cv.* Ratna/O. officinalis *to YSB*

Wide hybrids	Mean percentage of YSB infestation*		Score	Reaction to YSB
	Dead heart	White ear head		
BC_1F_1 (Savitri/ *O. brachyantha*)	12.50 (21.04)	10.50 (19.32)	3	MR
SC_1F_1 (Ratna/ *O. officinalis*) (P1)	14.23 (22.42)	9.03 (16.78)	3	MR
(P2)	13.50 (21.85)	8.82 (17.69)	3	MR
(P3)	12.83 (21.33)	10.01 (19.35)	3	MR
Ratna	27.00 (31.44)	20.36 (26.91)	5/7	MS/S
Jaya	47.08 (43.61)	39.81 (39.38)	7/9	S/HS
SEM	$\pm$1.489	$\pm$1.818		
C.D. at p=0.05	4.347	5.308		
C.V. (%)	12.36	17.50		

* Values in the parentheses indicate transformed values

The interspecific hybrids, viz. *O. sativa* (cv. Ratna, Jaya) and *O. officinalis*, *O. sativa* (cv. Savitri) and *O. brachyantha* were found to be moderately resistant (Table 2) (Panda and Sen, 2007). Further work is continuing to develop introgression lines with resistance to YSB through development of Monosomic Alien Addition lines (MAALs). Many insect and pathogen resistance genes have been transferred from wild rice to cultivated rice through wide hybridization (Jena and Khush, 1990).

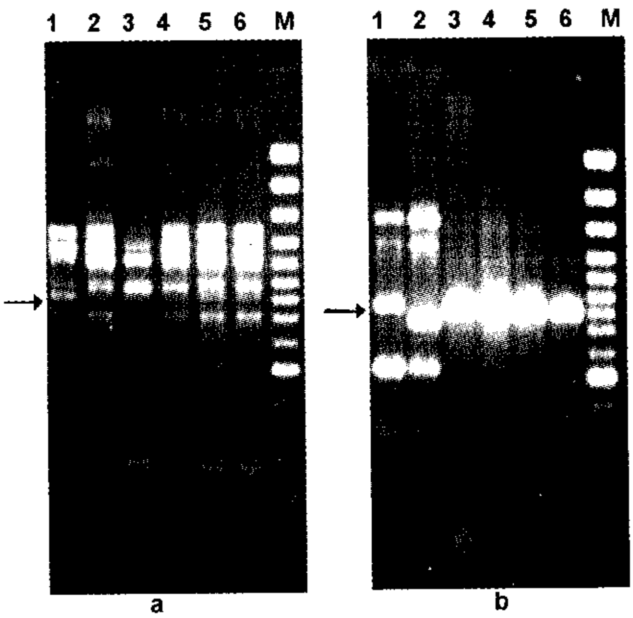

Fig. 2. Polymorphism of root knot resistant specific random markers (a) $OPO7_{825}$ and (b) $OPH8_{825}$ in resistant donors. Lane1 Ramakrishna, Lane 2-Annapurna, Lane 3-Tadukan, Lane 4-Tetep, Lane 5- TKM 6, Lane 6-Zenith, Lane 7-100 bp molecular weight markers. Arrows indicate the resistance specific markers.

Development of molecular markers for insect pest resistance

Five out 47 microsatellite primers, viz. RM152, RM547, RM3215, RM6208 and RM6429 amplified resistance specific polymorphic fragments of 150bp, 225 bp, 200 bp, 140 bp and 100 bp, respectively in PTB10 and resistant bulk. Amplification of these markers in individual RILs confirmed the linkage between markers and resistance gene, *Gm4* present in PTB10 (Behera *et al.*, 2007). Kosambi Mapping Function analysis mapped the markers, viz. $RM152_{150}$, $RM547_{225}$, $RM3215_{200}$, $RM6208_{140}$ and $RM6429_{100}$ at a distance of 14.9 cM, 1.9 cM, 11.26cM 2.8 cM and 4.8 cM, respectively from the resistance gene, *Gm4*. The order was found to be RM152-*Gm4*-RM547-RM6408-RM6429-RM3215. Further work is in progress to incorporate resistance gene, *Gm4* from Abhaya into high yielding varieties, Kavya, Lalat and Tapaswini using these microsatellite markers at CRRI.

The primer, OPH7 amplified resistance specific fragments of 698bp in resistant parent, ARC5984 while the primer, OPQ7 amplified susceptible specific fragment of 1150bp in susceptible parent, TN1. Amplification of these markers in individual RILs confirmed the linkage. The markers, $OPH7_{698}$ is linked to resistance gene at a distance of 16cM while OPQ_{1150} is linked to susceptibility at a distance of 30 cM (Lima *et al.*, 2007).

Two primers, viz. $OPH7_{825}$ and $OPH8_{825}$ amplified resistance specific fragments of 825 bp each in resistant parent, Ramakrishna. The linkage was confirmed on individual RILs. Both the markers, $OPH7_{825}$ and $OPH8_{825}$ were linked to the RKN resistance gene(s) at a distance of 7.14cM (Sahu *et al.*, 2005). The applicability of linked RAPD markers, $OPH8_{825}$ and $OPO7_{825}$ in marker assisted (MAS) breeding was studied in root knot nematode resistant donors, viz. Tadukan, Tetep, Zenith and TKM6. The linked markers, viz. $OPH8_{825}$ and $OPO7_{825}$ generated polymorphism between Annapurna and the resistant donors signifying that these markers can be used for transferring RKN resistance genes from diverse sources (Fig. 2a,b).

Marker assisted selection breeding

All the genotypes in the IR 64 background with single bacterial blight resistance gene *xa5* or *xa13* recorded resistant reaction at 5-7 locations while those with *xa21* were found resistant at only 3-5 locations. Among the genotypes possessing two genes, those with *xa5* and *xa13* showed resistance at more number of test sites. Among the different lines tested, six lines, viz. CRMAS2231-6, CRMAS2231-22, CRMAS2231-29, CRMAS2231-36, CRMAS2231-37 and CRMAS 2231-48 were identified as best and recommended for their registration and use as potential donors in future breeding programmes (Muralidharan *et al.*, 2004). Among the different Swarna pyramided lines tested, eight lines, *viz.* CRMAS2232-65, CRMAS2232-17, CRMAS2232-18, CRMAS2232-71, CRMAS2232-66, CRMAS2232-23, CRMAS2232-46, CRMAS2232-85 performed well and were comparable to the resistant check Ajaya, or some of them were even better than Ajaya.

Among the 25 gene pyramided lines in the background of IR64 tested, CRMAS2231-46 containing three genes of bacterial blight resistance *xa5, xa13 and Xa21* showed highest grain yield of 5072 kg ha^{-1} followed by high yielding check CR749-20-2 (5032 kg ha^{-1}), CRMAS2231-40 (4750 kg ha^{-1}) and tolerant check IRBB 60 (4606 kg ha^{-1}) against the susceptible check IR64 (4122 kg ha^{-1}). Among the twenty-two gene pyramided lines in the background of Swarna along with three check varieties, viz. Mahsuri, Rajshree and Swarna tested during wet season of 2004 at CRRI farm, one line CRMAS 2232-9 (6764 kg ha^{-1}) performed better than the best check Mahsuri (6425 kg ha^{-1}) followed by CRMAS 2232-24 (6377 kg ha^{-1}), CRMAS 2232-5 (6184 kg ha^{-1}) and CRMAS 2232-23 (5894 kg ha^{-1}).

Among 14 gene pyramided lines in the background of Kalinga III and Vandana, 10 lines, viz. CRMAS 2541-2, CRMAS 2541-5, CRMAS 2541-6, CRMAS 2541-7, CRMAS 2541-8, CRMAS 2541-9, CRMAS 2541-10, CRMAS 2542-1, CRMAS 2542-2 and CRMAS 2542-4 showed resistant reaction to blast with score of 1, while three lines, viz. CRMAS 2541-1, CRMAS 2541-4 and CRMAS 2542-3 showed resistance score of 2. CRMAS 2541-3 showed moderate resistance with SES score of 3. Further, these lines are in the process of evaluation for yield.

Molecular characterization of genetic variability in pathogen and insect populations

The isolates of *X. oryzae* pv. *oryzae* collected from different susceptible cultivars and land races in three regions in eastern India could be differentiated into 17 haplotypes that formed 12 lineages at 80% similarity level. The observed sub-structuring of the pathogen population may reflect differences in the germplasm used in the regions, which consist of modern and traditional cultivars.

Different isolates of bacterial blight and blast pathogens collected from different susceptible cultivars, land races, NILs, etc. were fingerprinted using molecular markers. The bacterial blight pathogen isolates collected from disease trap nursery and from experimental fields of CRRI, states of Andhra Pradesh, Punjab and Tamil Nadu were differentiated into 80 lineages at 60% similarity level. Of these, 59 lineages consisted of groups of isolates and 21 lineages consisted of single isolates. This information clearly brings out a wide variation in the occurrence of *X. oryzae* pv. *oryzae* lineages

Table 3. *Type of pathotypes of bacterial blight pathogen for the evaluation of IR 64 and Swarna NILs*

Pathotype	Origin/Host	Reaction on differentials						
		Xa3	***Xa4***	***Xa5***	***Xa7***	***Xa10***	***xa13***	***Xa21***
XB-1	Lunishree	R	S	S	S	S	S	S
XB-16	PR106	R	S	S	R	R	R	R
XB-18	Pankaj	R	S	R	S	S	S	R
XB-2	Manoharsali	R	S	S	S	S	S	R
XA3	Sonamani	S	S	S	S	S	R	S
XH-1	TKM 9	R	R	R	R	R	R	R

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XB-16	PR106	R	S	S	R	R	R	R
XB-18	Pankaj	R	S	R	S	S	S	R
XB-2	Manoharsali	R	S	S	S	S	S	R
XA3	Sonamani	S	S	S	S	S	R	S
XH-1	TKM 9	R	R	R	R	R	R	R

over space and time. Admittedly, the occurrence of the pathogen lineages is not only influenced by the host genotypes, but also by time and location. The reactions of resistance genes to some of the isolates indicated the possibility of deploying appropriate gene combinations in high yielding varieties (Table 3).

The blast population collected from Chhattisgarh (a hot spot for blast) was very diverse as it consisted of six lineages of the seven detected. Two lineages were detected among the isolates (small number examined so far) from Sikkim, which were also detected in Chhattisgarh and Orissa (Mishra *et al.*, 2006).

Four affected populations of root knot nematode could be differentiated from each other. Cuttack population showed highest similarity (i.e. 0.973) with Amana population while Tiruchinapalli population showed least similarity (i.e. 0.804) with Kamakhyanagar population. Low divergence among these three populations indicated that all the three populations could have originated from the same root knot pathotype and adapted to local environmental conditions of Orissa. Molecular genotyping showed that Tiruchinapalli population is different from Orissa populations although genetic diversity does also exist among Orissa populations (Kausal *et al.*, 2004).

Development of transgenic rice

Potato trypsin inhibitor transgene (PIN II) was introduced to elite *indica* cultivars, viz. Swarna and Pusa Basmati 1. Total of eleven plants were regenerated. Two transgenic lines each from Pusa Basmati 1 and Swarna with PIN II showed higher level of resistance to yellow stem borer and leaf folder (Fig. 3) (Ramana Rao *et al.*, 2001). Ever since the first report of successful production of transgenic rice in 1988, enormous progress has been made in the development of transgenic rice resistant to diseases and insects (Ye *et al.*, 2001, Sridevi *et al.*, 2003).

Molecular characterization of *Wolbachia*

The 16S rRNA gene specific primers amplified 870 bp fragment in rice gall midge, white backed planthopper, leaffolder, caseworm and mosquito. No amplification was found in brown planthopper, yellow stem borer, green leafhopper, riceskipper, mealybug and stinkbug suggesting the absence of *Wolbachia* in these insects. This was the first report of *Wolbachia* infection from India in white backed planthopper leaf folder and case worm (Behera *et al.*, 2001).

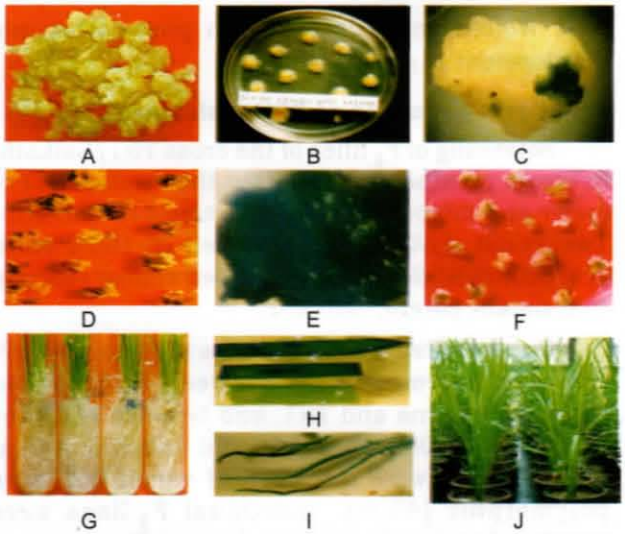

Fig. 3. Development of transgenic plants from callus through *Agrobacteriumtumefaciens* mediated transformation A) Selection of embryogenic calli, B) Co-cultivation of embryogenic calli with Agrobacterium, C) Histochemical GUS analysis of calli, D) Selection of callus on hygromycin, E) Histochemical GUS analysis of callus, F) Regeneration of transformed calli, G) Plantlets in rooting medium, H) Stable GUS expression (leaf blade), I) Stable GUS expression (roots) and J) Transformed plants.

Curing experiments were carried out to know the exact role of *Wolbachia* in rice gall midge. Treatment of eggs of gall midge with 0.05% tetracycline resulted in non-hatching of fertile eggs while 98.2%, 15.0% and 2.3 % of fertile eggs hatched into larvae in control, 0.01% and 0.025% tetracycline treatments, respectively. *Wolbachia* was detected in larvae (control and tetracycline treatment), fertile eggs (control) but absent in tetracycline treated fertile eggs (Table 4), indicating

***Table 4**. PCR amplification of Wolbachia in egg and larvae of rice gall midge*

Treatment	Egg/larvae	Number	Present	Absent
0.05%TC	E	20	0	20
0.025%TC	E	20	0	20
0.025%TC	L	20	20	0
0.01%TC	E	20	0	20
0.01%TC	L	20	20	0
C	E	20	20	0
C	L	20	20	0

TC – Tetracycline, C-control

that *Wolbachia* is essential in post-embryonic development of gall midge.

Functional genomics of BPH resistance

Screening of F_3 lines of the cross TN1/Salkathi to brown planthopper indicated the involvement of major and minor genes for resistance in Salkathi. Twenty out of 606 M_2 lines showed 70-100% death of seedlings while rest lines showed similar reaction to resistant parent, Salkathi.

One hundred-twenty primers (45%) out of 269 revealed polymorphism between susceptible cultivars, Swarna and TN1, and between resistant cultivars, viz. Dhobanumbari and Salkathi. A total of 543 bands were amplified of which 267 were polymorphic (49 %). Individual F_3 lines were genotyped with polymorphic microsatellite markers. Linear regression analysis indicated that three markers, viz. RM551, RM470 and RM 252 located on chromosome 4 were found to be associated with QTLs controlling resistance with maximum contributions of 4 %, 14 % and 3 % to reduction in mortality of seedlings, respectively. These QTLs express from the 3rd day after infestation and protect till 7th day when 100% of the susceptible cultivar, TN1 die. Nineteen major genes and several QTLs associated with BPH resistance have been in different rice cultivars, some of which have been introduced into elite lines using molecular breeding approach (Jena *et al.*, 2006).

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J. Indian Soc. Coastal agric. Res., 26(1), 55-57, 2008 **Invited Paper**

Environmental Factors Related to Water Resource Management for Sustainable Rural Development in the Krishna Delta, South India

JEAN-PHILIPPE VENOT[1], BHARAT SHARMA[2] and K. V. G. K. RAO[3]

[1]International Water Management Institute (IWMI, Hyderabad, India) & GECKO Laboratory, University of Paris X-Nanterre, France

[2]International Water Management Institute, New-Delhi, India

and

[3]Head, Consultancy Services, INDWA Technologies, Hyderabad, India

(E-mail: j.venot@cgiar.org, b.sharma@cgiar.org, kvgkrao@hotmail.com)

Basin water development, rural dynamics and the institutional setting of natural resource management in the Krishna basin have led to degradation of downstream coastal ecosystems. Reversing this evolution requires the formal recognition of the environment as a water user in its own right and the implementation of an environmental water provision that should be based on a two-tier allocation system with assured discharges in the irrigation canals of the Krishna delta and river discharges to the ocean. Other measures facilitating integrated natural resource management from the farm level to the basin level are needed too.

*(**Key words:** Water resource development, Environmental degradation, National water policy, Integrated management at regional level, Social & economic benefits, Role of resource users in decision making)*

Water use for urban, industrial and agricultural growth is approaching and, in some cases, even exceeding the availability of renewable water. Water resource development has led to significant degradation of various ecosystems. However, to date, most developing countries have paid little attention to water over-commitment and to its environmental consequences.

The Indian National Water Policy of 2002 provides guidelines for prioritizing water allocation to different competing sectors but does not mention how these priorities are to be translated on the ground. It provides precedence to drinking water over irrigation and hydropower. Industrial and navigational needs are given the last priority. Environmental concerns are mentioned and "ecology" is given fourth priority but nothing is said on how this could be achieved (GoI, 2002). Environmental water needs have not yet received the required attention in water policies and in the general discourse on water resource governance.

Balancing environmental requirements and human consumptive uses represents a considerable challenge in arid and semiarid areas of the developing world, as more vocal populations and associated water demand increase to sustain a broader economic development. This paper aims at understanding the interconnection between the environment and rural development in the Krishna basin, located in South India to match environmental concerns with the social and economic objectives of sustainable development.

STUDY AREA AND METHODS

The Krishna basin drains an area of about 260,000 km^2 and covers parts of three South Indian states, viz. Andhra Pradesh, Karnataka and Maharashtra. Its climate is predominantly semiarid, i.e. river flows are highly variable and this makes forecasting and management a challenge. Based on secondary data collection, field interviews with key informants and farmers, and a comprehensive review of the literature, this article investigates the linkages between basin water development, quantified by a 50-year basinwise water accounting, and the environment of the lower Krishna basin (in Andhra Pradesh, Fig. 1) to identify potential areas of intervention for environmentally sustainable agriculture in the Krishna delta. The lower Krishna basin has an area of 8,746 km^2 and represents three main ecosystems (Fig. 1).

- The Krishna delta, where a large irrigation project irrigates 540,000 hectare with gravity canals drawing water from a barrage on the Krishna river at Vijayawada, accommodates about 4 million inhabitants depending mainly on agriculture and aquaculture.
- The Kolleru lake, a freshwater inland lake and a Ramsar site, is located between the Krishna and Godavari river deltas. Aquaculture ponds are widespread in this region.

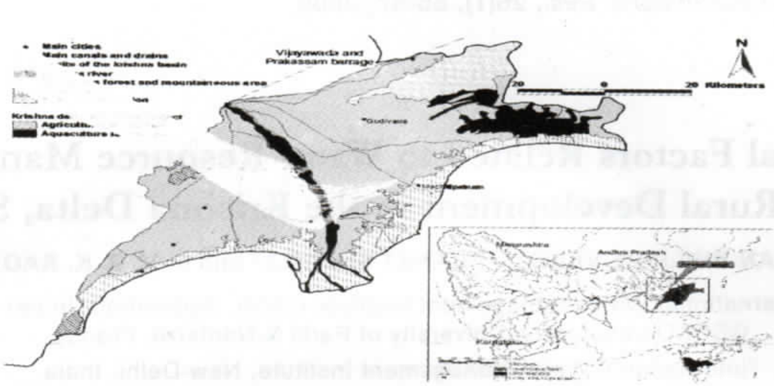

Fig. 1. The Lower Krishna Basin, South India (adopted from Venot *et al.*, 2008)

The coastal zone where mangroves and natural vegetation have been progressively cut and replaced by aquaculture ponds.

RESULTS AND DISCUSSION

Since the 1850s, the Krishna basin has witnessed a dramatic development of irrigation and water use. Infrastructure development hastened after India gained independence, with the construction of both large scale projects and minor irrigation schemes, and a booming ground water economy (Venot, 2008). This led to the progressive decline of river flows and to the closure of the river basin (e.g. nearly all available water is committed and river discharge falls short of meeting environmental functions, Molden, 1997, Molle *et al.*, 2007).

A basin-wise historical water accounting highlights that consumptive water uses (e.g. evapotranspiration from any kind of land cover and municipal, industrial and livestock processes) increased from 69 to 90 % of the basin net inflow between 1955-1965 and 1990-2000. In 1990-2000, river discharge amounted to 19.6 Bcm y^{-1}. According to a simple desktop assessment method developed by Smakhtin and Anputhas (2006) to assess the environmental status of Indian river basins, the ecosystems of the Krishna basin are moderately to largely modified. Water users and managers have only little room for maneuvering to cope with the drought and limit its adverse consequences on livelihoods and the environment. This has been tragically illustrated during the dry years of 2001-2004 that may foreshadow the conditions that will prevail in the Krishna basin in the near future, when the discharge to the ocean was almost zero (0.75 Bcm y^{-1} during the monsoon high flows), the rate of water commitment hiked to 99.6% without accounting for any environmental flows, and water shortage affected rural development, notably in the Krishna delta irrigation project and in the coastal region.

Declining river discharge leads to increasing salinity in the river channels (Saxena *et al.*, 2003). Smakhtin *et al.* (2007) also reported a tendency for land losses to the sea as little water with lower sediment load (due to sedimentation in the reservoirs upstream) reaches the ocean. Further, upstream water development has delayed river runoff by more than two months, which may be significantly impacting the timing of water releases in the canals of the Krishna delta. Low and delayed supplies in 2003 have for example resulted in a 58% decrease in paddy yields in the tail end region of the irrigation project (Venot *et al.*, 2008). Delaying the cropping season also caused considerable reduction in blackgram yields, the major r*abi* crop in the delta. Lower water availability implies shifting agricultural, economic and social conditions.

On another hand, the agrarian and institutional dynamics the Krishna delta has in itself have led to an environmentally unsustainable development of both ground water use and aquaculture. Environmental degradation in the lower Krishna basin has endogenous causes and manifests itself by aquifer and land salinization (the saline water-freshwater interface in the shallow aquifers of the delta has moved 30 km inland between 1976 and 2003), desiccating wetlands (the Kolleru lake has witnessed dramatic changes over the last 50 years and was nearly desiccated in the early 2000s though recent moves to remove fishponds are positive), disappearing mangrove covers, increasing water pollution, and frequent drinking water shortages (GoAP, 2001 and 2003). Natural resource management policies have been shaped by political and economic interests (the high profitability of the aquaculture sector that mainly benefited local entrepreneurs has been a major driver of the changes observed in the region) and have rarely resulted in equity of resource use or environmental sustainability.

Invalidating this statement will only be achieved by the formal recognition of the environment as a water user in its own right. This paper calls for a formal allocation of water to be set aside for the purpose of environmental preservation. This quantum of water has to be embedded in a broader framework for long term adoptive water allocation mechanisms (e.g. the current Krishna Water Disputes Tribunal) to meet growing and competing water demands, and to preserve the livelihoods of the poorest communities that bear the highest costs for environmental degradation. This environmental provision could be defined as a two-tier allocation. First, a given discharge in the irrigation canals of the Krishna delta will meet agriculture and domestic demand of the local population and the environmental requirements of ground water recharge, as well as salt leaching from the soil. Second, a fixed annual discharge to the ocean will limit seawater intrusion into the river branches and preserve the functioning of downstream ecosystems. Smakhtin and Anputhas (2006) evaluate that this would require between 6.5 and 14.2 Bcm y^{-1}. Water commitment would then become 94 to 98% of total water availability. Placing the preservation of ecosystems on the Indian water agenda requires convincing of the decision makers that providing environmental flows can produce environmental as well as economic and social benefits. One of the most promising ways to achieve this objective is through an economic valuation of the services sustained by ecosystems.

Finally, taking up the challenge of environmental preservation and sustainable agriculture in coastal areas requires not only maintaining a given flow to the ocean but also implementation of other policies from the local level to the regional and state levels. Those include:

- Technical solutions (reconfiguration of the surface and subsurface drainage systems), regulating farmers' practices (monitoring the use of fertilizers and pesticides through agricultural extension services), regulating ground water access and limiting the depth and number of wells (policies of electricity supply/ pricing and policies of access to credit)
- Integrated management at the regional level through delineation of zones with different development and environmental objectives. The Coastal Regulation Zone Notification of 1991 is a first step forward but its implementation remains problematic.

Other generic interventions such as strengthening the institutional context; facilitating the coordination between departments; maintaining a database on wetlands, mangroves, and soil and water salinization; and promoting the role of the resource users in the decision making process are commonly advocated too (GoAP, 2001). There is also a need for providing attractive alternatives to the poorest communities, i.e. crop insurance schemes, attractive output markets for farmers tempted to diversify, subsidies to adopt microirrigation, and creation of adequate non-farm livelihoods opportunities (Venot *et al.*, 2008).

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J. Indian Soc. Coastal agric. Res., 26(1), 58-62, 2008 **Invited Paper**

Sundarbans – the Greatest Mangal Diversity of the Planet

PRANABES SANYAL[1], A. D. MUKHOPADHYAY[2] and INDRANI DAS[3]

[1&2]School of Oceanographic Studies, Jadavpur University, Kolkata, India 700 032, India

and

[3]Department of Botany, Midnapore College, West Bengal, India 721 101, India
(E-mail: pranabes@gmail.com, pranabes@hotmail.com)

The Indian Sundarbans covers an area of 4264 km² of inter-tidal mangal vegetation including the network of creeks and rivers. The Bengal Basin is gradually tilting eastwards, as a result river Ganga and its distributaries are suffering from fresh water flow within India. This stress condition has given rise to luxuriant mangal diversity in Indian Sundarbans with 93 numbers of inter-tidal species belonging to 67 genera. Various authorities established that in South Asia and especially India mangrove floral diversity flourished best. Again, Sundarbans among Indian mangrove manifests the highest mangal diversity. The 'similarity indices' (Sorensen) and 'Generic diversity' (Williams) of these three mangrove forests have also been calculated.

***(Key words:** Major elements, Minor elements, Back mangal, Mangrove commensals, Mangrove associate)*

Indian Sundarbans is occupying 9630 sq km inter-tidal area of the erstwhile Ganga–Brahmaputra river delta. Owing to continuous neo-tectonic movement resulting in eastern tilt of Bengal Basin (Morgan and McIntire, 1959), the river Ganga has changed its course eastwards into river Padma. The Indian Sundarbans is suffering from paucity of fresh water from upstream. Milliman (1989) has also confirmed gradual subsiding nature of Bengal Basin along a hinge line extending from the mouth of river Hooghly to Dhaka in Bangladesh. Lack of fresh water has resulted in somewhat stressed condition for the Sundarbans mangrove. Owing to such stressed condition, luxuriant mangal diversity has developed within Indian part of the Sundarbans.

Definition, modification in the categorisation, of the mangal plants species

The definition of mangrove has become an issue of controversy and confusion particularly after the publication of a huge number of titles (7000) on the mangrove. Initially the name originated from Surinam inter-tidal plant association of Rhizophoraceae family members called "Mangue" groves. Later on, Chapman (1970) described 107 inter-tidal species out of which 55 were true mangroves and others were obligate mangroves. Tomlinson (1986) listed 54 species and divided them into "major elements" having characteristic mangal morphological manifestation and exclusive inter-tidal occurrence, "minor elements" (also found exclusively within intertidal zones), and "back mangal" which were found in both inter-tidal and beyond it.

Mepham and Mepham (1984) carried out extensive survey of inter-tidal species in tropical and subtropical world to find 900 species out of which all the plants could be located even within terrestrial areas except only two species, viz. *Nypa fruticans* and *Rhizophora mucronata*. They wanted to assign all the arborescent inter-tidal species as mangroves.

Wang *et al.* (2003) listed 115 woody mangrove species all over the world including 12 varieties. They also adopted the concept of woody inter-tidal, tropical and subtropical plants as mangrove having specially adapted morphological structures and physiological mechanisms (Wang *et al.*, 2003). They, however, distinguished the normal tidal range habitat from exclusive inter-tidal occurrence for the "true mangroves" not only at the generic level but mostly at family/ sub-family levels. Whereas, those occurring within spring tide or storm tide zones having exclusive inter-tidal occurrence at only generic level were termed as "semi-mangrove". Those plants occurring at inter-tidal edges as well as within terrestrial areas are considered as "mangrove associated" plants. They are halotolerant and halophilous. The climbers, epiphytes and herbs of such inter-tidal zones were considered "mangrove commensals" that even included inter-tidal species like herbaceous mangrove fern *Achrostichum aureum*. However, they included the woody stilt rooted mangrove climber *Acanthus volubilis* in their list as semi-mangrove species inspite of it being a climber.

In view of the above mentioned confusions, it has become expedient to consider the structure and functions of inter-tidal plants to determine their inclusion within mangrove list. The concept of "true mangroves" more or less matches with the concept of "major elements" of Tomlinson (1986). But, the occurrence at normal tidal level for the true mangrove (Wang *et al.*, 2003) is an important factor introduced by them. The exclusive inter-tidal pioneer saline grasses, occurring only within the normal tidal range, *Porterasia coarctata* and *Myriostachya wightiana* having profound salt excretory mechanism in the form of salt crystals on blades be considered as a "minor element" in the absence of mangrove morphological manifestations. Thus, *Acanthus illicifolius* that sometimes furnishes rudimentary stilting and has one of the highest concentrations of salt excretory glands (Sanyal and Bal, 1986) should be considered as 'semi-mangrove'. The stilt rooted mangrove exclusive climber *Acanthus volubilis* should be considered as 'true mangrove'.

MATERIALS AND METHODS

The studies were conducted only within Indian part of the Sundarbans (*latitudes*: 21°-30'N and 22°-45'N, *longitudes*: 88°-00' E and 89°-05' E). In Sundarbans the structure of mangrove depends on estuarine position (outer, mid- or inner estuarine), soil textures, salinity and geomorphology. On the relatively immature western Sundarbans Islands the soil is more psamitic (sandy), salinity is higher, and mangrove vegetation starts on the fresh deposition (Fig. 1) with *Porterasia coarctata* and *Acanthus ilicifolius*, followed by *Avicennia alba, Avicennia marina, Sonneratia griffithii, Sonneratia apetala*, and finally *Avicennia officinalis, Excoecaria agallocha, Phoenix paludosa* along the upward slope of tidal excursion. On the eastern portion the *Avicennia* and *Sonneratia apetala* take the foreshore particularly at the inner estuary (Fig. 2). The foreshore species like *Aegiceras corniculatum* in mid-estuarine zone is interspersed with *Rhizophora- Bruguiera* association. Presence of a matrix of *Ceriops* and *Excoecaria* dotted with sporadic *Xylocarpus granatum* and *X. mekongensis* are the characteristics of the mature areas of inner and mid-estuary. *Heritiera fomes* is the climax species in outer and mid- estuarine regions only at places where soil could get chance to mature. Being tide dominated delta the erosion–accretions process is faster in Sundarbans. The mature patches with *Excoecaria–Phoenix* association suffer vertical collapse and new succession starts. Thus, climax species *Heritiera fomes* does not get chance to grow very often or remain for longer life. It is only on stable geomorphological humps that *Heritiera fomes* grows better (good diameter growth) within the matrix of *Excoecaria–Ceriops* association. This apart, more than 50% of Sundarbans inter-tidal delta is now reclaimed and this forms the marginal mangrove habitat having occurrence of *Diospyros ferrae, Allophyllus cobbe, Pandnaus tectorius, Salvadora persica, Opuntia dilleni*, etc.

The Sundarbans forest is subdivided into sections depending on the distance from the mouth of the estuary as: 0 to 20 km - Outer estuary, 20 to 40 km - Mid-estuary, > 40 km - Inner estuary.

The surface water samples were collected and their conductivity was measured with portable conductivity meter. Similarly, the velocity of currents was measured with current meter for different creeks. Another stratification was made into eastern and western sector. Western sector comprises of relatively immature Islands. The species succession was found out from both the stratification as well as from all three sections.

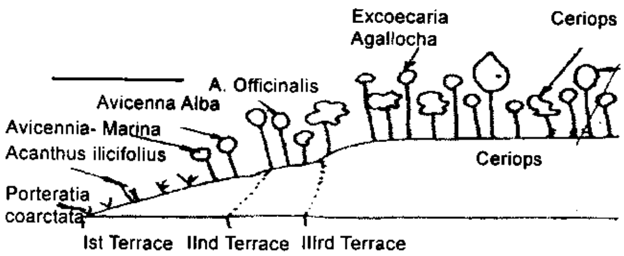

Fig. 1. Study of the sandy depositional sequence

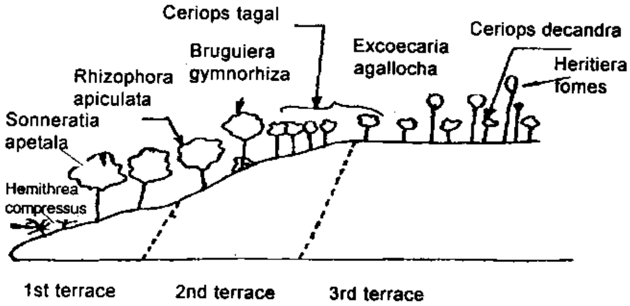

Fig. 2. Pelitic depositional sequence

RESULTS AND DISCUSSION

The monsoon freshets received by Sundarbans rivers Hooghly on west and Ichhamati on east were found to lower the salinity of outer estuary for six months of the year as in Table 1 (Sanyal *et al.*, 1984). This topsy-turvy distribution of salinity coupled with accelerated geomorphic activity of unabated tidal water leads to migration of species association from inner estuary to the mid- and outer estuary and *vice-versa*. Thus, when *Avicennia marina*, a typical outer estuarine species is found in the torrents of mid-estuary (having current speed > 0.5 m per second) it was found to have developed abnormal adaptation like stilt roots (Sanyal and Bal, 1986).

Calculations of comparative mangal diversity of Indian Sundarbans

Finlayson and Mosar (1991) estimated world mangrove cover to be 1.4 million ha. They pointed out that Indo-West Pacific (Tropical zone) and Australia have the most dominant mangroves and are important in respect of species diversity and richness of the mangrove. Within such richness Indian mangal diversity ranks highest (Naskar and Guha Bakshi, 1983).

The top three mangal diversities in India are the Sundarbans, Mahanadi river estuary of Orissa and mangal association of Andaman & Nicober group of Islands (Naskar, 1999). Abstracts of the comparative diversity in India for both arborescent and herbaceous inter-tidal species are furnished in Table 2 and 3, respectively.

The Sorensen Similarity Indices were calculated between:

Sundarbans and Mahanadi: S.I. = 0.8
Sundarbans and A & N Islands: S.I. = 0.7

Similarity Index formula is = $2A/(2A+b+c)$, where A = common species, b = only Sundarbans species, and c = A&N or Mahanadi species not found in Sundarbans.

The Generic Diversities (Williams, 1964) were also calculated as :

Total Mangal **Diversity**

	Sndrbn	A&N	Mahandi
Genus	67	39	45
Species	93	62	66
Generic Diversity	90.79	65.57	66.66

Finally, the definition of mangrove remains confusing owing to the input of enormous number of publications on global mangrove vegetation. Among these, the logic of Tomlinson (1986) appears to be acceptable to solve the confusion read together with the contention putforth by Wang *et al.* (2003) particularly on the mangrove commensals or tenants. Only mangrove fern *Achrosticum areum* with prominent stilting rhizoid and highly halophytic nature merit inclusion as 'semi-mangroves' of Wang *et al.* (2003) equivalent to 'minor element' of Tomlinson (1986). *Porterasia coarctata* and *Myriostachya wightiana*, the two saline grasses having excellent salt crystal excretory mechanism, also merit inclusion as 'semi-mangrove/ minor element' inspite of being non-arborescent.

The herbaceous mangrove exclusive species termed as mangrove commensals are separately classified as true, semi- and associated mangrove species in Sundarbans. Wang *et al.* (2003) identified globally 84 mangrove species belonging to 24 genera and 16 families among which 70 species belonging to 16 genera and 11 families are considered 'true mangroves'. In Sundarbans alone 25 species belonging to 15 genera and 11 families are considered as 'true mangroves', and 9 species are considered as 'semi- mangroves' belonging to 7 genera and 7 families. The lack of fresh water flow in Indian Sundarbans has given rise to a stress condition due to unabated tide from sea and have resulted in great diversity (37 species) of 'mangrove associates' or 'back mangal' of Tomlinson (1986). It is apparent that the present status of mangal diversity of Indian Sundarbans stands highest in India. However, any further stress due to further shortage of upstream fresh water could result in sudden fall of mangal diversity in Indian Sundarbans.

Table 1. *Seasonal variation of salinity of creek waters of Sundarbans at different estuarine positions*

Estuary Position	September	April	November
Outer estuary	16 dS/m	40.1 dS/m	20.07 dS/m
Mid-estuary	21 dS/m	34.3 dS/m	18.44 dS/m
Inner estuary	24 dS/m	38 dS/m	16.82 dS/m

***Table 2.** A comparative account of Mangal diversity in Sundarbans, Andaman & Nicober and Mahanadi river estuary*

	Sundarbans	A&N	Mahanadi
True Mangrove			
Family	11	10	10
Genus	15	14	14
Species	25	27	27
Semi-mangrove			
Family	7	8	8
Genus	7	8	8
Species	7+2 (Grasses)	10	9
Mangrove associate			
Family	18	9	11
Genus	28	13	18
Species	37	19	23
Total			
Family	36	27	29
Genus	50	35	40
Species	71	58	59
Total Mangal			
S/G	1.4271/50	1.65714358/35	1.4859/40
X	0.503	0.48	0.497
Generic Diversity	58.30	63.92	59.71
Mangrove commensals			
Family	10	4	4
Genus	17	4	5
Species	22	4	7

***Table 3.** Mangal Diversity of Indian Sundarbans*

True mangrove	Semi-mangrove
25	9
Total	
34	
Associated mangrove	
37	
Total	
71	
Mangrove commensals or tenants	
22	
Total	
93	

CONCLUSION

From the results of Sorensen's Similarity Indices it is apparent that Sundarbans mangals are more similar to Mahanádi than A&N Islands. It is also apparent from the Generic Diversity calculation (Williams,1964) that Sundarbans is having the highest Generic Diversity of 90.79 followed by Mahanadi mangal at 66.66. If however the Mangrove Commensals are not considered A & N Islands have the highest Generic Diversity.

ACKNOWLEDGEMENT

The authors thank Prof. Manju Banerjee (Fellow of National Academy of Sciences) of Department of Botany, Calcutta University for kindly critically going through the manuscript and offering valuable suggestions. The initial inputs of Dr. K.R. Naskar ex-National Mangrove Fellow are also acknowledged with thanks.

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J. Indian Soc. Coastal agric. Res., 26(1), 63-68, 2008

Invited Paper

Coastal Ecosystems: Monitoring, Mitigation and Management – Geomatics Approach

P. S. ROY and ARIJIT ROY

National Remote Sensing Centre, Indian Space Research Organization
Balanagar, Hyderabad – 500 037, India
(E-mail : psr@nrsa.gov.in)

Coastal ecosystems are some of the highly productive, dynamic and fragile ecosystems on the earth. Apart from harbouring the diverse and exquisite ecosystems such as mangroves and coral reefs, which are considered to be some of the most diverse ecosystems of the world, the coastal ecosystems also supply a large chunk of the marine protein for the human population. Due to presence of fertile soil and water, the coastal ecosystems are home to a large human population leading to over-exploitation of coastal and ocean resources, which is resulting in environmental degradation and habitat loss. Climate changes, sea surface warming and sea level oscillations are long term coastal processes which have impact on the coastal ecosystems. Relative sea level rise has a number of biogeophysical impacts such as increased erosion and flood potential. These processes modify the coastal physiography at a steady and slow pace. Short term processes such as *tsunami* run up, storm surges, cyclone and floods devastate coast through beach erosion, inundation, saline water intrusion, and sedimentation.

There is an immediate need for fast and effective monitoring of the coastal ecosystem especially in the tropical regions for effective management of the coastal resources for sustainable development. In this respect geo-informatics based inputs have been very effective in ecosystem monitoring, policy formulation and disaster mitigation in the coastal regions of India.

(Key words: *Coastal ecosystems, Management, Monitoring, Decision support system, Climate change)*

Fragile coastal ecosystems are under continuous threat by organic and chemical pollution from agriculture and industries as a result of growing population pressure and accelerated urbanization, and the resultant degradation of natural resources has reached now an alarming stage. In fact, coastal zones are vulnerable areas in different parts of the world, but in developing countries due to the population pressure and human population in a bid to extract the maximum output from the available sources, the impacts of degradation can be worse than in other countries (Jorge *et al.*, 2002). Sustainable development is an integrated and interactive approach that allows for the understanding of the complex relationship between society and nature. Respecting human rights and assuming that maintaining the environment in its present state is vital for the future of the human kind taking into account equity, security and environment is the essence of sustainable development (Lourenço, 2001). Unfortunately these unique ecosystems are under threat from both anthropogenic (goods like coral, from encroachment due to agriculture, aquaculture, urbanization and industrialization, Reddy and Roy, 2007) and natural influences (erosion, tidal surge, cyclones and *tsunami*).

Coastal ecosystems being the ecotone between the two very different ecosystems, the terrestrial and the marine have a number of complex interactions and exchange of energy and matter between them. This complex but delicate network of energy and material exchange has been maintaining the coastal ecosystems. But the increased human population pressure on the coastal ecosystems especially in the tropics has led to deleterious effect on these ecosystem processes and hence the coastal ecosystems are irreversibly undergoing changes. Some of the natural threats to the coastal ecosystems in Indian coastal regions are tropical cyclones, changes in precipitation, sea level rise (UNEP, 2005), temperature change and *tsunami* (GCRMN, 2005). These natural calamities cause immense devastation on the coastal communities, running into crores of rupees and affecting thousands of lives. Other threats and problems affecting the coastal ecosystems are erosion, flooding, submergence and encroachment of the natural systems. The coastal ecosystem management in India needs to focus on some of the key issues affecting the life and well being of the human population in the coastal regions. Among issues coastal land use and land cover dynamics of Space for national level projects and R & D activities. Described below are three case studies, viz. (1) database generation (as a part of DOS-DBT sponsored project on biodiversity characterization at landscape level), (2) monitoring of mangrove degradation in Phichavaram, and (3) study undertaken to analyze the human induced changes in and around the Coringa wild life sanctuary in Kakinada Bay.

Biodiversity characterization at landscape level – east coast

National Biodiversity Characterization at Landscape Level, a project jointly sponsored by Department of Biotechnology and Department of Space, has been implemented to identify and map the potential biodiversity rich regions in India. This project has generated spatial information at three levels, viz. satellite based primary information (vegetation type map, spatial locations of roads and villages, fire occurrence), geospatially derived or modeled information (disturbance index, fragmentation, biological richness), and geospatially designed stratified field samples. As a part of biodiversity characterization at landscape level the database on biodiversity status and distribution of east coast of India has been completed. This region harbours unique mangrove vegetation of India. The mangrove regions are generally situated in the delta, are one of the most productive areas and also biologically very rich. Although in the rest of east coast much of the mangrove areas have been degraded, some pockets still remain in some parts of Orissa, Andhra Pradesh and Tamil Nadu. Mangroves are unique ecosystem by virtue of special ecological functions. The buffering strength against the coastal processes provided by them is pivotal in preserving the coastal landmass and its inhabitants (NRSA, 2007) (Fig. 1).

Mangrove degradation

Mangroves are morphologically adaptive coastal vegetation found in tropical and subtropical climatic conditions. Generally, significant changes in environmental conditions alter the vigour or zonations of vegetation (Jimenez *et al.*, 1985). Worldwide mangroves are undergoing degradation due to change in sedimentation rates, soil subsidence, insufficient freshwater mixing, lack of tidal forces, and sea level rise.

Human induced changes in the coastal ecosystem

Coastal locations have been the favourite destination of population for defence, commercial and other economic reasons. About 20% of the population of India lives in coastal areas, a larger percentage of this being in coastal cities, such as Mumbai, Chennai and Kolkata. One of the major factors responsible for the degradation of coastal ecosystems is the growth in human population that requires space for settlement and other resources like soil and water.

Recent work by Reddy and Roy (2007) has shown that the coastal ecosystems are dynamic ones and is extensively influenced by anthropogenic factors and policies. The encroachment of the natural mangroves by agriculture and aquaculture during 1980s has led to extensive degradation of the mangrove vegetation in the Kakinada Bay. But after declaration of the Coringa Wild life sanctuary the mangrove vegetation in the Kakinada Bay has shown positive increment.

Disaster management and mitigation

Orissa supercyclone: The east coast of India has been affected by a minimum of four high intensity cyclones every year for the past 100 years (Raghavan and Sen Sharma, 2000). In October 1999, 12 coastal districts in Orissa suffered from severe damage, 9885 persons died, 2142 people were injured, and 12 lakh houses were damaged. Similarly, more than 10,000 lives were lost around the Krishna delta in Andhra Pradesh in 1977 (Mascarenhas, 2004). Coastal hotels and resorts were inundated and habitations destroyed at Digha in August 1997. Most of the masses that occupy countless lowlying plains comprise farmers who live in mud houses; this section of society bears the recurring loss of humans, livestock and property.

Remote sensing based information was one of the main inputs for relief and rescue operation carried out by the Government of India. The 100 year data on sea level rise and vegetation type characteristics (for Sundarbans) are shown in Fig. 2(a,b). The impact and extent of flooding as a result of the cyclone also helped in aid allocation and prioritization of the relief aid distribution in the affected areas (Fig 2c).

Tsunami: The *tsunamis* of Sunday 26 December 2004 caught many people unprepared and unaware in Indian Ocean countries. The *tsunamis* resulted in more than 250,000 people killed or missing and caused massive destruction to coastal resources and infrastructure. Remote sensing has helped in generating the spatial extent of the damage to the coastal regions of the Indian Ocean. National Disaster Management at NRSA has generated

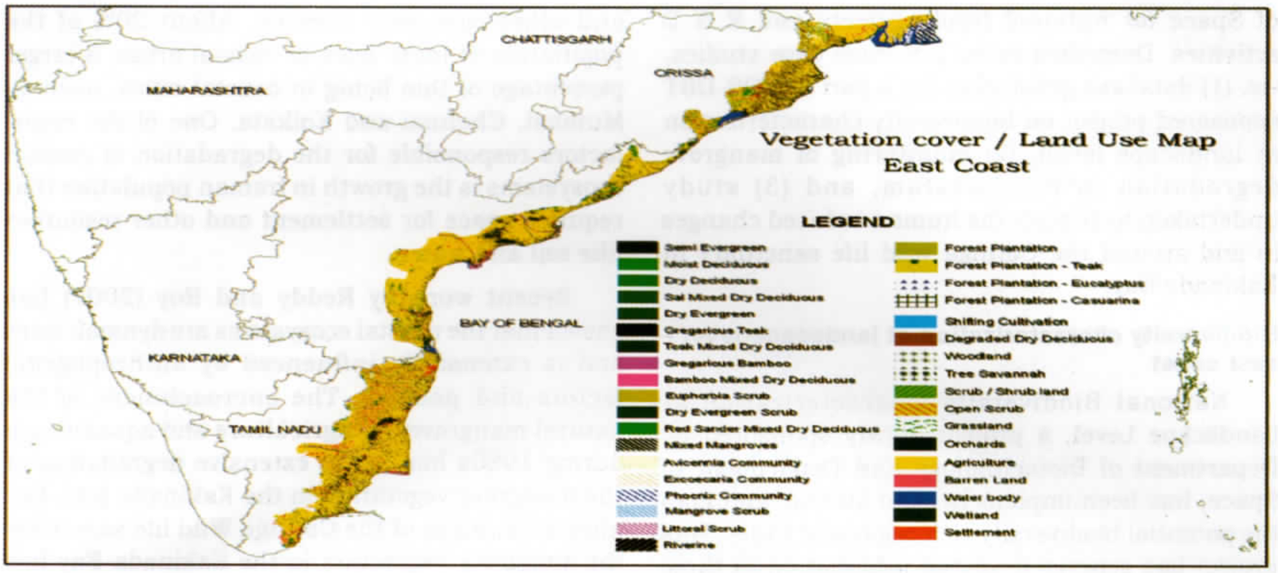

Fig. 1. Vegetation cover/ land use map of east coast (Source: NRSA, 2007)

extensive aerial database of the affected areas along the east coast of India and also Srilanka. The vivid spatial images on the extent and intensity of damage have helped in allocation and prioritization of rescue and aid to the affected people (Fig 2d).

Environmental impact assessment

Most of the industries prefer the coastal regions due to access to adequate amount of water, availability of manpower, and for easy discharge of effluents to the sea. The impact of the industrial pollutant and the pressure on the coastal ecosystem due to the increased population has led to rapid degradation of the fragile coastal ecosystem. Remote sensing and GIS based environmental impact assessment of the various natural and anthropogenic changes in the coastal areas gives the policy makers quick information of the environmental status to take necessary remedial action and to make necessary changes in the policy. This is exemplified by the recent government order banning aquaculture in the vicinity of Kolleru lake.

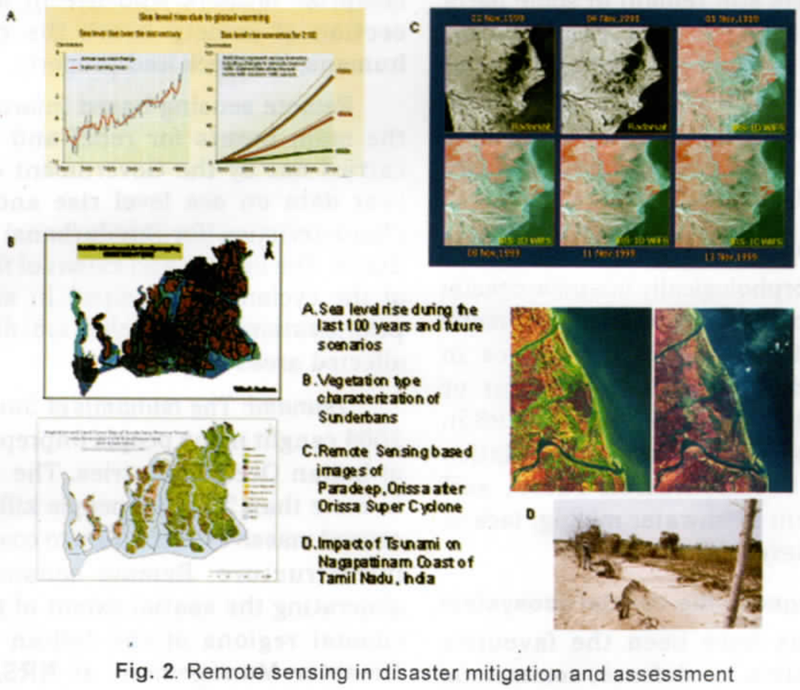

Fig. 2. Remote sensing in disaster mitigation and assessment

The extent of erosion and sediment transportation due to *tsunami* has also been effectively carried out using RS and GIS techniques.

The economic development of the coastal areas also needs pre- and post- developmental environmental impact assessment as well as feasibility studies. Recently, work carried out by NRSA for Central Electric Authority (CEA) for identification of potential sites for establishment of thermal power plants along the east and west coast have exemplified the effectiveness of RS & GIS in this exercise after ensuring that these are agriculturally unproductive, away from protected natural habitats, and away from CRZ. The sites identified by this process have been taken up by the CEA for further development of the project sites for establishment of the thermal power plants.

Identification of potential fishing zone (PFZ)

Geomatics has played a very important role in the lives of fishermen for optimizing the catch and identification of potential areas for the catch. Satellite remote sensing applications in fisheries have concentrated on the measurement of ocean temperatures and colour and computation of ocean transport based on satellite measured wind stress and sea level variability. The information about important oceanographic conditions and processes affecting fish populations, such as surface temperature isotherms, oceanic frontal boundaries, currents, circulation patterns and coastal upwelling can be deduced by using ocean surface temperature measurements made by satellites. Ocean temperature measurements made by satellite remote sensing are useful in defining the distribution of marine fish habitat conditions.

CONCLUSION

Both climatic change and human activities affect biodiversity and productivity of coastal habitat. Shoreline development and protection disrupt the ability of coastal habitats to withstand natural process. Waste discharge, increase in sediment and nutrient supply adversely impact the environment. Coastal planners are facing the problem of differentiating human induced changes from naturally forced changes on the coastal zone especially while prioritizing the coastal issues for Indian Coastal Zone Management (ICZM) plan preparation. Both naturals and human induced impacts have direct or indirect effect on coastal ecosystem and its services. Our ability to measure, assess and predict the natural and human effects, pressures and their dimensions becomes complex. In the present context, ecosystem approach becomes sustainable and safer coastal zone management practice. There are efforts to improve ecosystem management by integrated, adaptive and experimental approach. The common goal in these approaches is synthesis of real time or near real time data for evaluation, monitoring, and preparation of strategic solution for protection, restoration and conservation. Remote sensing data supplemented with field validations and near real time *in situ* observations have become a primary source for generation of spatial and temporal information particularly for coastal ecosystems, developmental activities, etc. and to some extent to accurately assess the underlying causes for various coastal issues/ problems. Geographic information system provides total solution for spatial data organization, modelling, monitoring and also to develop decision support systems.

Coastal decision support system: Coastal Information System is a network of database repositories each having a specialized area of database maintenance and updation for monitoring and management of ecosystems. The major databases required for coastal information system are biodiversity, land use and land cover, climate, coastal geomorphology and coastal feature (bathymetry, tidal, sea level fluctuation, topography, etc.). These databases form the basis of information on coastal vulnerability assessment, impact assessment, disaster management and eco-informatics by appropriate geo-statistical analysis and modelling. These databases will be linked to a central server, which will store the data for analysis, and will be known as Coastal Information System. This will be linked to an expert system shell for queering and decision making forming the Coastal Decision Support System (Fig. 3).

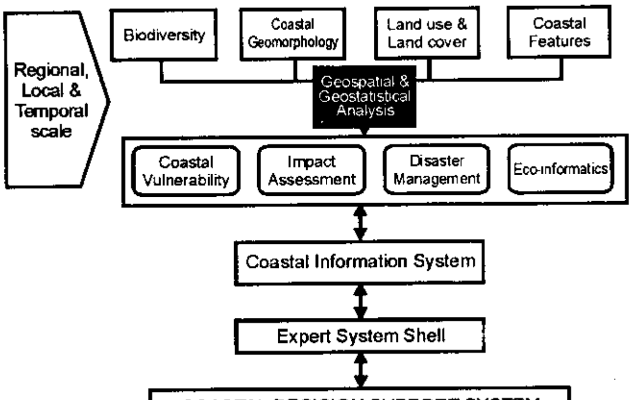

Fig. 3. Schematic diagram for Coastal Decision Support System

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Proceedings of the International Symposium of

Indian Society of Coastal Agricultural Research
on
Management of Coastal Ecosystem: Technological Advancement and Livelihood Security

at Science City, Kolkata, India, October 27-30, 2007

Sponsored by

Indian Council of Agricultural Research, New Delhi
Dept. of Land Reforms, Ministry of Rural Development, Govt. of India, New Delhi
Council of Scientific & Industrial Research, New Delhi

The International Symposium on '*Management of Coastal Ecosystem: Technological Advancement and Livelihood Security*' was organized by Indian Society of Coastal Agricultural Research in collaboration with Central Soil Salinity Research Institute (ICAR), RRS, Canning, India; Central Research Institute for Jute and Allied Fibres (ICAR), Barrackpore, India; Central Inland Fisheries Research Institute (ICAR), Barrackpore, India; National Bureau of Soil Survey & Land Use Planning, Kolkata Centre (ICAR), Kolkata, India; Indian Society of Soil Science-Kolkata Chapter, Kolkata, India and Veterinary Council of India (West Bengal State), Kolkata, India. The International Symposium was held under the following 12 technical sessions in 5 sub-themes.

Sub-theme – I : Sustainable development of coastal areas through agriculture and allied activities

Technical session 1	Crop husbandry and technological transfer
Technical session 2	Horticultural and plantation crops
Technical session 3	Soil resource management and inventorization
Technical session 4	Hydrology and water management
Technical session 5	Veterinary and dairy sciences
Technical session 6	Fishery sciences
Technical session 7	Crop protection

Sub-theme – II : Coastal disaster management for improved livelihood security

Technical session 8	Disaster management

Sub-theme – III : Wetland management, mangroves and agro-forestry

Technical session 9	Pollution, environment and ecology
Technical session 11	Mangrove, wetland, dunes

Sub-theme – IV : Oceanography, coastal energy and information technology

Technical session 10	RS, GIS, Marine sciences

Sub-theme – V : IPR, Coastal policy

Technical session 12	IPR, coastal policy and economic issues

The Symposium was inaugurated by Shri Sailen Sarkar, Minister-in-Charge, Dept. of Parliamentary Affairs & Environment, Govt. of West Bengal. Prof. Swapan K. Dutta, Rash Behari Professor, University of Calcutta delivered the Key-note address in the inaugural session of the symposium. Dr. M.V. Rao, Ex-Special DG, ICAR & former VC, ANGRAU, Dr. S. Ayyappan, DDG (Fisheries), ICAR and Dr. K.M. Bujarbaruah, DDG (Animal

Sciences) delivered plenary lectures in the symposium. Delegates from 70 National Institutes and Universities and several Institutes from abroad were attended the International Symposium. In different technical sessions there were 65 papers both invited and voluntary contribution for oral presentation and 85 voluntary papers for poster presentation.

Following awards were conferred during the course of the seminar:

a) Fellow of the Society :

i) Dr. Deepak Sarkar, Head , NBSS&LUP, Kolkata Centre, Kolkata, West Bengal

ii) Dr. S.Ghoshal Choudhury, Sr.Scientist, CARI, Port Blair, A&N Islands.

b) Dr. J. S. P. Yadav Best Paper Award (for the years 2004 and 2005) :

The Award went to D.K. Kundu, Ravender Singh & S. Roy Chowdhury for their paper entitled "Mulch and irrigation effect on nutrient availability in soil and tuber yield of sweet potato (*Ipomea batatas* L.) in coastal Orissa" appearing in Vol.23, No.2 at pages 106-109.

c) Dr. H.S.Sen Best Poster Award :

The Award went to the paper authored by G.V. Laxmi and A.K. Biswas on "Nitrate in groundwater in intensive agricultural areas of West Godavari: A case study"

Following action points emerged out of the deliberations during technical sessions.

- Development of suitable rice varieties with multiple stress tolerance for different sub-regions of coastal ecosystem through conventional and marker assisted breeding and transgenic approaches for yield enhancement and stability.
- Development, validation and dissemination of site-specific crop management practices for rice and rice-based cropping systems
- Development of suitable rice-based farming systems and strategies for value addition from various agricultural produce for income and employment generation.
- Conservation of genetic resources through both *ex situ* and *in situ* method for fruit, vegetable and tuber crops to prevent genetic erosion and further utilization in coastal Agri./Hort. system.
- Accessibility of the small and marginal farmers of the coastal areas to the quality seed, planting materials and hybrids of the horticultural crops.
- Improvement of the target horticultural crops suitable to coastal ecosystem through consorted breeding approaches.
- Promotion of cost effective production system in the coastal areas through demonstration and farmer school approach.
- Creation of awareness of pesticide residue effect on health and market value of the produce and training of the farmers regarding good agricultural practice and production of safe produce.
- Make rural farmers more competitive to improve income and livelihood through creation of farmer groups and linking them with direct supply chain.
- Post harvest management of the produce to be strengthened.
- Poverty alleviation and mitigation of micronutrient deficiency through the concept of home garden in coastal areas.
- Promotion of organic production of fruits and vegetables in coastal areas.
- Promotion of protected cultivation of high value vegetables in coastal areas.
- Conservation and promotion of indigenous vegetables for biodiversity security and diet variability in coastal ecosystem.
- A thorough inventorization of coastal soils needs be done particularly on soil fertility problem to decide upon the need of location specific ameliorating measures, and the ameliorants.
- To upkeep soil health/quality of coastal zone studies on soil biology is advocated and conjoint application of inorganic, organic and biological sources of nutrients needs to be popularized.
- A periodic monitoring and assessment of coastal areas/estuaries as to the impairment of its environment particularly for Tsunami like events, heavy metals including arsenic and other industrial pollutants is recommended by networking institutes of relevance.

- Potential of seawater, the most effective weapon to mitigate scarcity of water resources in coastal regions for use in various sectors of economy be investigated on war footing. It calls for cost cutting in currently available technologies for their popularization and widespread use.
- Soil salinization and groundwater quality are serious constraints in increasing the production and productivity of coastal States. A holistic approach for using these waters including wastewaters be initiated. Climate change, which is now a reality, is likely to aggravate these problems. Interrelationship between soil and groundwater salinity and seawater rise be investigated.
- Seawater intrusion has assumed a serious dimension in many states of India. Studies to assess the extent, its distribution and mitigation measures be initiated without loosing time.
- Long-term environmental impact of prawn culture and other similar livelihood options should be investigated particularly addressing the small and marginal farmers. Intensive prawn culture farming should be discouraged due to its known environmental hazards.
- Scope of value addition to around 6 million tons of milk available in coastal areas needs to be encashed through appropriate technology delivery mechanism involving different stakeholders in partnership mode.
- Conservation and improvement strategies for indigenous livestock & poultry germplasm resources need to be developed and implemented urgently to benefit coastal livestock growers socio-economically.
- Livestock based integrated models developed in coastal belt of Andaman & Nicobar be validated and propagated with necessary refinement in other coastal areas.
- Feed resource inventorization, mapping and optimizing nutritive value through tested technological interventions needs priority for supporting and sustaining production base.
- Faster animal disease diagnostic kits/reagents needs to be popularized and mass used to protect, manage and control the diseases and parasites.
- Skill development/ upgradation programme of the stakeholders together with information dissemination to farming community using print and electronic media be taken up.
- Region-specific agro-aqua integrated farming system models for the coastal areas are developed and demonstrated.
- Water management in coastal areas with due emphasis on all aspects of agricultural activities including fisheries and aquaculture with particular reference to discharge of freshwater to the estuary for maintaining a balance in salinity and ecosystem functioning.
- Comparative studies on economics of different species of shrimps and identification of areas in disease free shrimps for achieving the necessary diversification in coastal aquaculture.
- Enabling environment for strengthening coastal aquaculture as an important activity with support policy instrument and incentives, including alternate livelihood for deserving fishers..
- Various biotechnological tools and techniques such as embryo rescue technique, DNA marker technology, transgenic & functional genomics, RAPD markers, micro satellite markers and Recombinant Inbred lines (RIL) developed from susceptible and resistant lines can be used for identifying the disease causing genes as well as controlling the genes/chromosomes in suppressing that particular character which causes diseases.
- Apiculture can boost up crop production and economy in coastal belt of country.
- Studies/monitoring all the effect of tsunami on different aspects of soils, agriculture, livestock, fisheries, socio-economic conditions of farmers will be highly beneficial/educative to all, be it scientists, planners or administrators.
- Studies on ecological stability of coastal area as affected by natural disasters deserve attention and careful study.
- Integrated developmental planning for the coastal zone involving all the stakeholders, policymakers and NGOs in a public-private participatory mode.
- Use appropriate management strategy for harnessing maximum yield output in the handicapped ecology of coastal ecosystem in the face of continued threat from global warming and associated climate change.
- With increasing pressure on land from anthropological and industrial use, future agriculture is going to shift to marginal lands of the coastal ecosystem. The scientific community and policymakers should make utmost effort to stave off the upcoming challenge.

- Using NDVI, the process of early warning of agricultural drought should continue.
- Generation of disaster vulnerability maps of coastal areas be completed at an earliest.
- Salt affected soil maps as prepared by NRSA, DOS be made available to the concerned departments, as and when requested by them.
- Crop yield and acreage estimation as being done by DOS to continue.
- VRC program to be hastened.
- All departments be linked to Decision Support Centre (DSC) for disaster mitigation, generating data, including coastal floods and disseminating computerized data base.
- There is a need to generated status report of Indian mangroves species.
- Longterm monitoring is necessary to study the effect of tsunami cyclones and climate change on soil – plant/mangroves/fisheries etc.
- Studies may be conducted on effect of sea level rise on mangrove species etc.
- There is need to develop watershed based developmental programme with fisheries and livelihood in mind for landless people for which awareness programme and capacity building is needed.

  Study may be initiated to understand the process of higher nutrient level at the bottom /sediment characterization through sequential extraction
- Study may be initiated on medicinal properties of mangrove plants.
- Rehabilitation of degraded mangrove areas at mass scale after raising nursery must be given priority.
- Conservation, Protection and management of marshland biodiversity.
- Review of Institutional Mechanism and Capability – For carrying out with a proposal on Integrated Coastal Agricultural Authority (It may be a part of rainfed authority or independent- A decision need to be taken).
- Question building capabilities need to be developed for

  Research: i) Multi-disciplinary studies and arrangements to determine the potential maintenance of the coastal zone and its vulnerabilities for achieving sustainable development. ii) Cost benefit analysis need to be carried for developing integrated coastal zone management programmes. iii) Continuous monitoring and assessment programme to collect data, asses results and increase the availability and accessibility of information to all interested persons/ users.

  Education: Interdisciplinary curriculum needed to upgrading the skills of Coastal managers.

  Extension: Knowledge and technology transfer and Public awareness galvanizing by the local institutions

  Ultimately the results of scientific research and information to be integrated in policy development, planning and decision making.
- Necessity of peoples participation for (i) identification of problems and priorities in consultation with local interests such as identification of opportunities for future development of coastal areas, (ii) suitable system of data generation, retrieval, access, management by trained professionals and to create public awareness, (iii) institutional arrangements for coordination and enforcement, (iv) smarter science and policy development programmes, (v) how we need to address the fear of imbalanced balances ? A pro-active watch dog kind of mechanism essential to control the imbalances.

The Plenary session was chaired by Dr. J.S.P.Yadav, President, Indian Society of Coastal Agricultural Research. Dr. H.S.Sen, Hony. Secretary, ISCAR proposed vote of thanks. The seminar ended with thanks to the chair.

(H. S. Sen)

(Organizing Secretary, International Symposium)

DELEGATES ATTENDED THE SYMPOSIUM

1.	Shri Sailen Sarkar	Hon'ble Minister, Parliamentary Affairs & Environment, Govt. of WB
2.	Prof. Kangjoo Kim	Kunsun National University, Korea
3.	Mr. Seokhwi Kim	Kunsun National University, Korea
4.	Mr. Minhyung Lee	Kunsun National University, Korea
5.	Dr. Pradip Bhattacharyya	Kunsun National University, Korea
6.	Dr. A. M. Ismail	I.R.R.I,. Philippines
7.	Dr. R. K. Singh	I.R.R.I., Philippines
8.	Dr. Jean Phillipe Venot	France
9.	Dr. Md. Abdul Hasem	Bangladesh Agril. University, Bangladesh
10.	Dr. Md. Abdul Ghani	Bangladesh Agril. University, Bangladesh
11.	Dr. Md. S. Alam	Bangladesh Agril. University, Bangladesh
12.	Dr. Md. A. Kabir	Bangladesh Agril. University, Bangladesh
13.	Dr. Md. S. Bari	Bangladesh Agril. University, Bangladesh
14.	Dr. N. Naher	Bangladesh Agril. University, Bangladesh
15.	Dr. Md. K. Hasan	Bangladesh Agril. University, Bangladesh
16.	Dr. J. S. P. Yadav	New Delhi
17.	Dr. M. V. Rao	Hyderabad
18.	Dr. S. B. Kadrekar	Ratnagiri
19.	Dr. A. K. Bandyopadhyay	Kolkata
20.	Dr. M. L. Chaddha	I.C.R.I.S.A.T., Hyderabad
21.	Dr. A. K. Bandyopadhyay	NABARD, Kolkata
22.	Dr. N. K. Tyagi	A.S.R.B., New Delhi
23.	Dr. S. Ayyappan	I.C.A.R., New Delhi
24.	Dr. P. S. Minhas	I.C.A.R., New Delhi
25.	Dr. D. K. Paul	I.C.A.R., New Delhi
26.	Dr. V. S. Korikanthimath	I.C.A.R. Complex for Goa, Goa
27.	Miss Varsha Dhananjay Raikar	Goa University, Goa
28.	Dr. P. E. Shingare	Kharland Research Station, Panvel
29.	Dr. R. L. Kunkerkar	R.A.R.S., Karjat
30.	Dr. Jagadish Chandra Tarafdar	C.A.Z.R.I., Jodhpur
31.	Dr. Shantilal Gordhan Savalia	Junagarh Agril. University, Junagarh
32.	Dr. N. B. Babaria	Junagarh Agril. University, Junagarh
33.	Dr. K. B. Polara	Junagarh Agril. University, Junagarh
34.	Dr. J. V. Polara	Junagarh Agril. University, Junagarh
35.	Dr. M. S. Solanki	Junagarh Agril. University, Junagarh
36.	Dr. K. B. Parmar	Junagarh Agril. University, Junagarh
37.	Dr. V. R. Naik	Navsari Agril. University, Navsari
38.	Dr. V. D. Barvalia	Navsari Agril. University, Navsari
39.	Mr. N. R. Bhatt	M. G.. Science Institute, Ahmedabad
40.	Dr. B. Ganesh Kumar	N.C.A.P., New Delhi
41.	Dr. Kamal Kumar Datta	N.C.A.P., New Delhi

42.	Dr. J. S. Sundaresan Pillai	C.S.R.I., New Delhi
43.	Dr. A. L. Ramanathan	Jawaharlal Nehru University, New Delhi
44.	Miss Rita Chauhan	Jawaharlal Nehru University, New Delhi
45.	Mr. Arindam Datta	National Physical Laboratory, New Delhi
46.	Dr. R. J. Ravindra	I.C.A.R., New Delhi
47.	Dr. Sushil Kumar	N.D.R.I., Karnal
48.	Dr. S. K. Gupta	C.S.S.R.I., Karnal
49.	Dr. J. C. Dagar	C.S.S.R.I., Karnal
50.	Dr. Subha Jyoti Das	Central Ground Water Board, Bangalore
51.	Dr. S. Vadivelu	N.B.S.S. & L.U.P., Bangalore
52.	Dr. K. Kumar	P.J.N. College of Ag. & Res. Instt., Karaikal
53.	Dr. Uma Bagavathi Ammal	P.J.N. College of Ag. & Res. Instt., Karaikal
54.	Dr. A. Pouchepparad Jou	P.J.N. College of Ag. & Res. Instt., Karaikal
55.	Dr. Ramaswamy Sankar	P.J.N. College of Ag. & Res. Instt., Karaikal
56.	Dr. Annamalai Baskar	P.J.N. College of Ag. & Res. Instt., Karaikal
57.	Dr. Pathusa Mohideen Nasurudeen	P.J.N. College of Ag. & Res. Instt., Karaikal
58.	Dr. Krishnasamy Paramasivam	P.J.N. College of Ag. & Res. Instt., Karaikal
59.	Dr. Latha Ramaiyan	P.J.N. College of Ag. & Res. Instt., Karaikal
60.	Dr. V. Kanthaswamy	P.J.N. College of Ag. & Res. Instt., Karaikal
61.	Dr. V. Krishnan	P.J.N. College of Ag. & Res. Instt., Karaikal
62.	Dr. J. Alice Retna Sujeetha	P.J.N. College of Ag. & Res. Instt., Karaikal
63.	Mr. C. Isaac Sunil	P.J.N. College of Ag. & Res. Instt., Karaikal
64.	Dr. V. N. Varma	Directorate of Agri. Paducherry
65.	Dr. Kalia Perumal Manivannan	Annamalai University, Annamalai Nagar
66.	Dr. R. Singaravel	Annamali University, Annamalai Nagar
67.	Dr. K. Suneetha	Annamalai University, Annamalai Nagar
68.	Dr. P. K. Mandal	National Res. Centre for Oil Palm, Pedavegi
69.	Dr. J. S. Parihar	S.A.C (ISRO), Ahmedabad
70.	Dr. G. Behera	N.R.S.A., Hyderabad
71.	Dr. D. M. hegde	D.R.R., Hyderabad
72.	Dr. G. Swarajya Lakshmi	Dept. of Bio-Resources Mgmt., Hyderabad
73.	Dr. G. V. Lakshmi	A.N.G.R.A.U., Bapatla
74.	Dr. M. Raghu Babu	Saline Water Scheme, Bapatla
75.	Dr. P. Ravindra Babu	Saline water Scheme. Bapatla
76.	Dr. Tapan Adhikari	Indian Instt. of Soil Science, Bhopal
77.	Dr. J. K. Saha	Indian Instt. of Soil Science, Bhopal
78.	Dr. R. H. Wanjari	Indian Instt. of Soil Science, Bhopal
79.	Dr. A. K. Biswas	Indian Instt. of Soil Science, Bhopal
80.	Dr. A. R. Khan	I.C.A.R. Complex for Eastern Region, Patna
81.	Mr. Bhupendra Singh Naik	C.S.W.C.R.T.I. Research Centre, Koraput
82.	Mr. D. P. Singh.	C. R. R. I., Cuttak
83.	Dr. K. R. Mahata	C. R. R. I., Cuttak

84.	Dr. Sanjay Saha	C. R. R. I., Cuttak
85.	Dr. P. Sen	C. R. R. I., Cuttak
86.	Dr. M. P. Pandey	C. R. R. I., Cuttak
87.	Mr. B. C. Marndi	C. R. R. I., Cuttak
88.	Dr. Annie Poonam	C. R. R. I., Cuttak
89.	Dr. T. K. Adhya	C. R. R. I., Cuttak
90.	Dr. D. P. Sinhababu	C. R. R. I., Cuttak
91.	Dr. L. Behera	C. R. R. I., Cuttak
92.	Dr. Santosh Kumar Srivastava	NRC for Women in Agriculture Baramunda, Bhubaneswar
93.	Dr. K. Laxminarayana	Reg. Centre of C.T.C.R.I., Bhubaneswar
94.	Dr. Archana Mukherjee	Reg. Centre of C.T.C.R.I., Bhubaneswar
95.	Dr. M. Nedunchezhiyan	Reg. Centre of C.T.C.R.I., Bhubaneswar
96.	Dr. P. K. Mukhopadhyay	C.I.F.A., Bhubaneswar
97.	Dr. R. B. Singandhupe	W.T.C. for Eastern Region, Bhubaneswar
98.	Dr. S. K. Pattanayak	O.U.A.T., Bhubaneswar
99.	Dr. M. K. Padhi	Reg. Centre of C.A.R.I., Bhubaneswar
100.	Dr. S. K. Ambast	C.A.R.I., Port Blair
101.	Dr. S. Ghoshal Chowdhury	C.A.R.I., Port Blair
102.	Dr. S. Jeya Kumar	C.A.R.I., Port Blair
103.	Dr. Krishna Kumar	C.A.R.I., Port Blair
104.	Dr. K. M. Agrawl	I.I.S.W.B.M., Kolkata
105.	Miss Sarbani Mitra	I.I.S.W.B.M., Kolkata
106.	Mr. Indranil Sadhukhan	I.I.S.W.B.M., Kolkata
107.	Miss Swati Nandi	I.I.S.W.B.M., Kolkata
108.	Miss Ishani Chatterjee	I.I.S.W.B.M., Kolkata
109.	Dr. A. Zaman	B.C.K.V., Kalyani
110.	Dr. A. B. Sarangi	B.C.K.V., Kalyani
111.	Dr. G. C. Hazra	B.C.K.V., Kalyani
112.	Dr. J. K. Hore	B.C.K.V., Kalyani
113.	Dr. S. S. Roy	B.C.K.V., Kalyani
114.	Dr. M. C. Kundu	B.C.K.V., Kalyani
115.	Dr. S. Chakraborty	B.C.K.V., Kalyani
116.	Dr. A. K. Dutta	B.C.K.V., Kalyani
117.	Dr. D. K. Murmu	B.C.K.V., Kalyani
118.	Dr. S. Pramanik	B.C.K.V., Kalyani
119.	Dr. S. K. Ghoshal	B.C.K.V., Kalyani
120.	Dr. A. Pariari	B.C.K.V., Kalyani
121.	Dr. N. Chattopadhyay	B.C.K.V., Kalyani
122.	Dr. S. Mitra	B.C.K.V., Kalyani
123.	Dr. N. Nair	B.C.K.V., Kalyani
124.	Dr. M. R. Khan	B.C.K.V., Kalyani

125.	Dr. K. Karmakar	B.C.K.V., Kalyani
126.	Dr. P. Hazra	B.C.K.V., Kalyani
127.	Dr. Biswapati Mandal	B.C.K.V., Kalyani
128.	Prof. A. K. Som Chaudhury	B.C.K.V., Mohanpur
129.	Prof. R. K. Ghosh	B.C.K.V., Mohanpur
130.	Dr. B. N. Panja	B.C.K.V., Mohanpur
131.	Dr. N. N. Mandal	B.C.K.V., Mohanpur
132.	Dr. A. K. Senapati	B.C.K.V., Mohanpur
133.	Dr. S. Pal	B.C.K.V., Mohanpur
134.	Dr. P. P. Dhar	B.C.K.V., Mohanpur
135.	Dr. K. Sheik	B.C.K.V., Mohanpur
136.	Dr. P. K. Sarkar	B.C.K.V., Mohanpur
137.	Dr. S. Mahato	B.C.K.V., Mohanpur
138.	Dr. P. K. Sahu	B.C.K.V., Mohanpur
139.	Dr. K. Barui	B.C.K.V., Mohanpur
140.	Miss Sonali Biswas	B.C.K.V., Mohanpur
141.	Mr. Abhijit Saha	B.C.K.V., Mohanpur
142.	Dr. D. Chakraborty	R.R.S.S., B.C.K.V., Sekharpur
143.	Dr. P. B. Chakraborty	R.S.S., B.C.K.V., Kakdwip
144.	Dr. Asis Bhattacharaya	Kolkata
145.	Dr. S. K. Das	E.R.S. of I.V.R.I., Kolkata
146.	Dr. D. N. Jana	E.R.S. of I.V.R.I., Kolkata
147.	Dr. R. N. Roy	E.R.S. of I.V.R.I., Kolkata
148.	Mr. Pradip Gupta	Dept. of PA&E, Govt. of W.B., Kolkata
149.	Mr. Sujit Sarkar	Dept. of PA&E, Govt. of W.B., Kolkata
150.	Mr. Kaushik Saha	Dept. of PA&E, Govt. of W.B., Kolkata
151.	Mr. N. J. Maitra	R.K. Ashram Krishi Vigyan Kendra, Nimpith
152.	Dr. S. N. Singh	Estuarine Fisheries Res. Centre of CIFRI, Vodadara
153.	Dr. Y. S. Yadav	B.O.B.P., Chennai
154.	Dr. T. C. Santiago	C.I.B.A., Chennai
155.	Dr. A. Panigrahi	K.R.C. of C.I.B.A., Kakdwip
156.	Prof. K. C. Dora	U.A.H. & F.S., Kolkata
157.	Dr. S. Saha	C.I.C.F.R.I., Barrackpore
158.	Dr. D. Nath	C.I.C.F.R.I., Barrackpore
159.	Dr. M. K. Mukhopadhyay	C.I.C.F.R.I., Barrackpore
160.	Dr. N. M. Laskar	C.I.C.F.R.I., Barrackpore
161.	Dr. Amitabha Ghosh	C.I.C.F.R.I., Barrackpore
162.	Dr. B. B. Satpathy	C.I.C.F.R.I., Barrackpore
163.	Dr. K. R. Naskar	C.I.C.F.R.I., Kolkata
164.	Dr. A. K. Dutta	W.A.D. of C.I.F.A., Rahara
165.	Dr. N. M. Chakraborty	W.A. Divn., Kalyani
166.	Dr. S. P. Rai	W.A.D. of C.I.F.A., Rahara

167.	Dr. B. N. Paul	W.A.D. of C.I.F.A., Rahara
168.	Dr. B. K. Pandey	W.A.D. of C.I.F.A., Rahara
169.	Dr. S. C. Mandal	W.A.D. of C.I.F.A., Rahara
170.	Dr. B. Sundarmurthy	Fisheries College & Res. Instt.
171.	Dr. S. K. Patra	A.I.C.R.P., Nadia
172.	Dr. S. Mandal	Baruipur
173.	Dr. K. Ghosh	Calcutta University, Kolkata
174.	Dr. Swapan Dutta	Calcutta University, Kolkata
175.	Dr. K. Chakraborty	Calcutta University, Kolkata
176.	Dr. S. Barua	Calcutta University, Kolkata
177.	Dr. N. Ghosh	Calcutta University, Kolkata
178.	Dr. Sudipta Tripathi	Calcutta University, Kolkata
179.	Dr. P. Sanyal	Jadavpur University, Kolkata
180.	Dr. A. Banerjee	Surendra Nath College, Kolkata
181.	Dr. K. K. Vass	C.I.F.R.I., Barrackpore
182.	Dr. H. S. Sen	C.R.I.J.A.F., Barrackpore
183.	Dr. B. Maji	C.R.I.J.A.F., Barrackpore
184.	Dr. M. N. Saha	C.R.I.J.A.F., Barrackpore
185.	Dr. A. K. Jana	C.R.I.J.A.F., Barrackpore
186.	Dr. C. R. Biswas	C.R.I.J.A.F., Barrackpore
187.	Dr. S. K. Jha	C.R.I.J.A.F., Barrackpore
188.	Mr. D. Moitre	C.R.I.J.A.F., Barrackpore
189.	Dr. S. Sarkar	C.R.I.J.A.F., Barrackpore
190.	Mr. A. Mukhopadhyay	C.R.I.J.A.F., Barrackpore
191.	Mrs. Nibedita Bose	C.R.I.J.A.F., Barrackpore
192.	Mr. Subrata Biswas	C.R.I.J.A.F., Barrackpore
193.	Mrs. Sanchalika Acharyya	C.R.I.J.A.F., Barrackpore
194.	Mrs. Subha Das	C.R.I.J.A.F., Barrackpore
195.	Mrs. Paramita Palit	C.R.I.J.A.F., Barrackpore
196.	Mr. Arnab Das	C.R.I.J.A.F., Barrackpore
197.	Mr. Raju Ghosh	C.R.I.J.A.F., Barrackpore
198.	Mr. S. K. Ghosh	C.R.I.J.A.F., Barrackpore
199.	Dr. A. R. Bal	C.S.S.R.I., Canning
200.	Dr. B. K. Bandyopadhyay	C.S.S.R.I., Canning
201.	Dr. A. B. Mandal	C.S.S.R.I., Canning
202.	Mr. S. K. Dutt	C.S.S.R.I., Canning
203.	Dr. D. Burman	C.S.S.R.I., Canning
204.	Dr. D. Pal	C.S.S.R.I., Canning
205.	Mr. S. Ray	C.S.S.R.I., Canning
206.	Mr. S. Mandal	C.S.S.R.I., Canning
207.	Mr. B. K. Ray	C.S.S.R.I., Canning

Proceedings of the General Body Meeting of
Indian Society of Coastal Agricultural Research
held on 29.10.2007 at Science City, Kolkata, West Bengal

The General Body Meeting of the Indian Society of Coastal Agricultural Research was held on 29th October at 04.00 p.m. at Science City, Kolkata. Dr. J. S. P. Yadav, President of the Society acted as the chairman. At the onset Dr. H. S. Sen, Honorary Secretary of the Society welcomed all the members to the General Body Meeting. The Chairman informed the house about the progress and growth of the Society. He expressed his satisfaction on the growth of the Society in terms of membership numbers and other activities. He greatly appreciated the enormous contribution by the senior most vice-president, Dr. S.B. Kadrekar, the Patron of the Society, Dr. M.V. Rao and other office bearer for the progress of the Society. He expressed his satisfaction due to increasing number of participation of women scientists. He also expressed his desire that Society will contribute more in future to fulfill its goal.

Dr. H. S. Sen Honorary Secretary on behalf of the executive council of the Society expressed his sincere thanks and gratitude to the organizing Institutes viz. Central Soil Salinity Research Institute (ICAR), Regional Research Station, Canning Town, West Bengal; Central Research Institute for Jute and Allied Fibres (ICAR), Barrackpore, West Bengal; National Bureau od Soil Science & Land Use Planning, Kolkata Centre, West Bengal; Central Inland Fisheries Research Institute (ICAR), Barrackpore, India; National Bureau of Soil Survey & Land Use Planning, Kolkata Centre(ICAR), Kolkata, West Bengal; Indian Society of Soil Science-Kolkata Chapter, Kolkata, West Bengal and Veterinary Council of India (West Bengal State), Kolkata, members of different organizing committees and conveners of different technical sessions for organizing International Symposium on '*Management of Coastal Ecosystem: Technological Advancement and Livelihood Security*' very successfully.

Agenda Item No.1 : Confirmation of the proceedings of the last GB Meeting

The minutes of the proceedings of the last General Body Meeting held at CTCRI, Thiruvananthapuram, Kerala on 22nd December, 2005 were confirmed.

Agenda Item No. 2 : Review of Action taken report and future recommendations

Action taken Report on the last meeting held on 22.12.2005 at Thiruvananthapuram was presented by the Hony. Secretary of ISCAR, and the future recommendations were recorded. The members expressed their satisfaction on the action taken report.

Future Recommendations :

- The committee constituted of Dr. A. K. Bandyopadhyay, Dr. H.S. Sen and Dr.B.K. Bandyopadhyay presented the revised bi-laws of the society and it was unanimously accepted by the GB.
- The proposal for requesting Dr. J.S. P Yadav, the former Chairman of ASRB & President of ISCAR and Dr. S.B. Kardekar, former VC of BSKKV, Dapoli & Vice-president of ISCAR as the Patron of the Society by for their enormous contribution in research and development to the cause of coastal agriculture was unanimously accepted.
- Efforts would be made to form regional Chapters of the Society. It was suggested that Chapters may be formed in Maharastra and Orissa, and all other regions where there are large number of members.
- Some of the funds of the Society may be kept in the nationalized bank as fixed deposit.

Agenda Item No. 3 : Statement of Accounts

The audited statement of accounts for the last financial year i.e. 2006-2007 as on 31-03-2007 was presented by Shri S. K. Dutt, Treasurer of the Society.

Receipts		Expenditure	
Opening Balance	1,85,325.76	Journal Printing	1,65,030.00
Membership Subscription	7,500.00	Postage etc. for Publication	25,805.00
Journal Subscription	32,320.00	Vehicle Hiring & Traveling	106.00
Sale of old papers	63.50	Printing, Stationary & Secretarial costs	4,158.00
Grants-in-Aid	1,67,500.00		
Donation etc.	65,000.00	Postage	3,923.00
Interest from Bank	36,217.00	Misc. Expenses	1,500.00
		Closing Balance	2,93,404.26
	4,93,926.26		**4,93,926.26**

The statement was accepted by the GB.

Agenda Item No. 4 : Review of membership subscription rates

The present membership subscription rates were discussed and following revised rares were decided.

Membership subscription rates:

	India, Bangladesh, Pakistan & Sri Lanka	Other countries*
Individual (Annual)	Rs. 200.00	US$ 150
Admission fee for Individual (Annual)	Rs. 50.00	US$ 10
Individual (Life Members)	Rs. 2,000.00	US$ 1,500
Institutions & Libraries (Annual)	Rs. 1,500.00	US$ 500
Institutions & Libraries (Life Members)	Rs. 15,000.00	US$ 5,000

Agenda Item No. 5 : Approval of the Executive Council recommendations held on 26th October, 2007

Proceedings of the previous meeting of the Executive Council held on 26th October, 2007 at NBSS&LUP, Kolkata were confirmed.

Agenda Item No. 6 : Election of Office bearers to the Executive Council

It was decided that following committee would conduct the election of the office bearers of the Society.

Election Committee : Dr. Biswapati Mandal- Chairman
Dr. A. K. Jana - Member
Dr. M. Saha - Member
Shri S. K. Dutt - Memeber

Agenda Item No. 7 : Other items

- The venue for the next National Seminar of the Society was discussed and it was proposed that it will be held at Dapoli. Dr. S. B. Kardekar offered all helps for holding the next National Seminar at Dapoli.

The chairman again thanked all the members present for participating in the meeting. The meeting ended with thanks to the chair.

Members present at the General Body Meeting of the Indian Society of Coastal Agricultural Research held on 29-10-2007 at Science City, Kolkata, West Bengal

1. Dr. J. S. P. Yadav, New Delhi
2. Dr. S. B. Kadrekar, Ratnagiri
3. Dr. A.K. Banyopadhyay, Kolkata
4. Dr. H. S. Sen, Barrackpore
5. Mr. S. K. Dutt, Canning
6. Dr. M. V. Rao, Hyderabad
7. Dr. B. K. Bandyopadhyay, Canning
8. Dr. S. K. Gupta, Karnal
9. Dr. D. Burman, Canning
10. Dr. S. Sarkar, Barrackpore
11. Dr. R. K. Singh, Philippines
12. Dr. A. R. Bal, Canning
13. Dr. A. B. Mandal, Canning
14. Dr. S. K. Ambast, Karnal
15. Dr. R. B. Singandhupe, Bhubaneswar
16. Dr. S. K. Jha, Barrackpore
17. Dr. G. V. Lakshmi,.Bapatla
18. Dr. A. K. Jana, Barrackpore
19. Dr. J. C. Dagar, Karnal
20. Dr. B. Maji, Barrackpore
21. Dr. C. R. Biswas, Barrackpore
22. Dr. D. P. Singh, Cuttack
23. Dr. A. K. Sahoo, Kolkata
24. Dr. Sudipta Tripathi, Kolkata
25. Dr. R. Singeravel, Annamalai
26. Dr. D. Pal, Canning
27. Dr. Sanjoy Saha, Cuttack
28. Dr. P. Sen, Cuttack
29. Dr. K. R. Naskar, Kolkata
30. Dr. M. Rahgu Babu, Bapatla
31. Dr. J. V. Polara, Junagadh
32. Dr. V. R. Nayak, Navsari
33. Dr. V. D. Barvalia, Navsari
34. Dr. K. D. Sah, Kolkata
35. Dr. M. Ravindra Babu, Bapatla
36. Dr. Krishnendu Das, Kolkata

**Guidelines to the Authors for manuscript style for publication of Articles in the *Journal of the Indian Society of Coastal Agricultural Research*

Sequence for a full length Paper : Title, Authors' name, Address & e-mail id, Abstract, Key words, Introduction, Materials and Methods, Results and Discussion, References

Sequence for Short communication: The title is to be followed by other sections without any heading(s), the name of authors, addresses and references are to be given at the end of the manuscript.

Title: Title case (as: Evaluation of Rice Varieties for Salt Affected Soils), Bold, 14 pt. (Times New Roman), Single space, Centre alignment (as: **Evaluation of Rice Varieties for Salt Affected Soils**)

Name of the authors: Upper case, Bold, 12 pt. (Times New Roman), Centre alignment, Single space (as: **T.N. SEN, U. K. DAS, and T. C. ROY**)

Address where the work was conducted : Title case, 12 pt. (Times New Roman), Centre alignment, e-mail id. For additional address the author's name be superscripted with the full address given as foot note in the first page. (as: **T.N. SEN, U. K. DAS[1], and T. C. ROY)**

Abstract: Without heading, Bold, 12 pt. (Times new Roman), Justified alignment, Double space

Key words: in bracket, italics, each item starts with a capital letter and items are separated by a coma, 12 pt. (Times New Roman), Justified alignment, Double space (as: ***Key words**: Copper fungicides, Movement of copper, Iron deficiency*)

Introduction: Without heading, 12 pt. (Times New Roman), Justified alignment, Double space

Materials and Methods : With heading (Centre alignment), Upper case, Bold, 12 pt. (Times New Roman): **Text**: Justified alignment, Double space, 12 pt. (Times New Roman) (as: **Materials and Methods**)

Results and Discussion : With heading (Centre alignment), Upper case, Bold, 12 pt. (Times New Roman): **Text**: Justified alignment, Double space, 12 pt. (Times New Roman) (as: **Results and Discussion**): **Table:** Title in italics at the top of the Table and Table number with a space (as: **Table 3.** *Characteristics of the soil profiles*): **Figure:** Title in italics at the bottom of the Figure and Figure number with a space (as: **Fig. 3.** *Salinity of groundwater in different months*)

References : With heading (Centre alignment), Upper case, Bold, 12 pt. (Times New Roman):

Journal articles: Sen, P.A., Roy, D. and Das, C. K. (2007). Characteristics of salt tolerant rice varieties for the coastal region. , **Journal name and volume:** Fully expanded name of the Journal, 12 pt. (Times New Roman), italics with volume in bold number as: *Journal of the Indian Society of Coastal Agricultural Research* **25**: 45-52.

Books: (i) Jackson, M. L. (1973). *Soil Chemical Analysis*. Asia Publishing House, New Delhi. 498p.

(ii) Biswas, T. D. and Mukherjee, S. K. (1989). In *Text Book of Soil Science*, pp. 153-221. Tata McGraw-Hill Publishing Company Limite, New Delhi.

Book Chapter: Inasi, K. A. and Philip, J. (1996). Crop production strategies of tuber crops. In *Tropical Tuber Crops*, G. T. Kurup and V. P. Potty (eds.), Kalyani Pub., Ludhiana, pp. 264-274.

Bulletin: Bandyopadhyay, B. K., Maji, B., Sen, H. S. and Tyagi, N. K. (2003). *Coastal Soils of West Bengal — Their Nature, Distribution and Characteristics*. Technical Bulletin **1/2003,** CSSRI. RRS, Canning Town, India, 62p.

Symposium Proceedings: Pampattiwar, P. S. and Mane, T.A. (1983). Evaluation of sprinkler method of irrigation for summer groundnut, Proceedings National Seminar on *'Evaluation of sprinkler irrigation'*, pp. 88-88, organized by the Indian Society of Agricultural Engineers, held during January 2-5, 2008 at Engineering Staff College, Pune, Maharastra, India.

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** For further clarification the Authors(s) may consult the latest volume of the Journal