Technological Interventions for Rehabilitation of Cyclone Affected Areas

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Introduction

Natural disasters like cyclone, tsunami, typhoons are major natural disasters in coastal areas. The devastation to lives, infrastructure, and agricultural lands and animals leave the people in the region to lose hopes of reviving their lives after such catastrophe. The farming community is worst affected by destruction of standing crops by seawater influx, contamination of wells from salt water, uprooting of coconut trees in coastal areas, loss of productive lands due to salt water ponding, degradation of lands due to sediment deposits or erosion, loss of agricultural tools, loss of small livestock and draft animals, and destruction of fisheries.

After each such disaster in first phase, the people survive on cash grants given by the government and nongovernmental organizations (NGOs) and on their savings, with their self-confidence at very low levels. The government/NGO initiate a work for cash programme that provided immediate relief and incomes around Rs 1500–2000 per month, but the reduction in status from honourable farmers to daily wage labourers badly affect their self-esteem. Surveys of farmers' behavioral changes, using open-ended questionnaires, has suggested that nearly 80% of respondents decide to abandon agriculture and were expecting the government to announce relief packages for their livelihood and alternative employment opportunities.

Thus the challenge is restore farming through interventions aimed towards restoring natural resources and the self-esteem and confidence of farmers. There are very few case studies on level of interventions to rehabilitate agriculture in post disaster situation. Post tsunami of 2004, a study was conducted in the Andaman Islands with the objective of restoring livelihoods through agricultural technologies.

Methodology

A study was conducted by the Central Agricultural Research Institute, Port Blair, during 2005–2008 to evaluate various agricultural technologies for use in tsunami-affected areas of the Andaman Islands to restore the livelihood of farmers. Immediately after the tsunami, damage and losses in terms of crops, land, livestock and fisheries for four selected villages were assessed through the Participatory Rural Appraisal (PRA) technique. On the basis of this assessment, low-lying coastal areas were categorized in different situations, and agricultural technologies were identified for each situation and evaluated in the study area.

Results and Discussion

There were three situations out of which, only two will be prevalent and therefore presented here:

Situation I: Tidal Inundation

Assessment of Spatial and Temporal Variability in Soil

One of the main impacts of the tsunami was salt accumulation, raising fears of strong decreases in soil fertility and productivity.

The texture of typical soils in the study area is sandy clay loam with medium organic carbon content (0.55%) in the upper 25 cm. The soil is acidic (pH 5.9), and its electrical conductivity (ECe) is 0.32 and 0.04 dS m^{-1} at 0–15 and 15–30 cm depths, respectively. Exchangeable calcium and magnesium content are typically 1.8 c mol (p+)/kg soil at 0–12 cm depth and 3.3 c mol (p+)/kg soil at 55 cm depth. After seawater intrusion, the surface soil (0–15 cm) became highly saline, with ECe ranging from 7.6 to 34.4 dS m^{-1} and pH ranging from 5.3 to 6.9. The salinity increased (ranging from ECe 9.7 to 28.4 dS m^{-1}) as soluble salts percolated downward from the surface soil.

After one rainy season, there was appreciable reduction in soluble cation and anion concentrations in all tsunami-affected soils, which in turn resulted in reduced ECe values. The surface-soil ECe of the School line soil series (Guptapara) went from 11.2 to 6.8 dS m^{-1}, and a similar trend was observed in the Dhanikari series. In the Mithakhari, Loha Barrack, and New Manglutan surface soils (Thushnabad series), the ECe decreased from 34.4 to 14.1 dS m^{-1}, from 20.2 to 9.4 dS m^{-1}, and from 7.6 to 4.5 dS m^{-1}, respectively. Similar trends were observed in the subsurface soils. The reason is leaching of soluble salts by high rainfall of the 2005 rainy season (3774 mm, greater than the average rainfall of 3075 mm). These results were in tune to other studies conducted in the region (Ghosal Choudhary, 2009; Ghosal Choudhary et al., 2009; Nayak et al., 2009; Rajat et al., 2009).

After two rainy seasons, there was a drastic reduction in soluble salt concentration of tsunami-affected agricultural lands. The surface soil ECe ranged from 3.9 to 8.3 dS m^{-1}, and the subsurface soil ECe ranged from 3.7 to 7.6 dS m^{-1}. The soil pH was also approaching the pre-tsunami level in most cases. It appears that the construction of low barriers (bunds) along the shore has prevented the entry of seawater into agricultural lands. However, this has also resulted in stagnation in many places, for which interventions are required. Water samples collected immediately after the tsunami showed contamination of both wells and ponds by seawater, with ECe ranging from 2.3 to 11.8 dS m^{-1} from chlorides and sulphates of sodium. However, the level has reduced after one rainy season. The ECe level has further decreased after two rainy seasons, and in most places it is below 2 dS m^{-1}. Methodologies for reclaiming saline and saline-sodic soils after irrigation in arid and semiarid regions may not be suitable for the Andaman and Nicobar Islands. In the Andamans, the analytical results revealed that the $2Na^{+}/Cl^{-} + SO_4^{2-}$ and

$CO_3^{2-} + HCO_3^-/Cl^- + SO_4^{2-}$ ratios were less than one. Thus, application of amendments like gypsum is not required, and leaching through rainwater impoundment alone will be effective in reclamation of the tsunami-affected agricultural lands. Construction of raised embankments along with sluice gates to regulate the ingress of seawater in these areas will improve the productivity of degraded natural resources by restricting the entry of seawater into the field during high tide and allowing drainage of rainwater that may collect during the rainy season during low tide.

Technological Interventions for Managing Degraded Natural Resources

A sea dyke along with a self-operated sluice structure was constructed to arrest intrusion of seawater into agricultural land. Once the ingression was stopped, three interventions were made in the area to enhance productivity.

Raised Beds

Seven farmers' fields were selected and converted into cultivable land by the raised bed method. Raised beds 1 m wide and 0.3 m high were created after field preparation (Figure 9). Chopped coconut husks (Figure 10), followed by soil mixed with compost, were applied before planting crops of high-value vegetables. The raised beds facilitated survival of vegetable crops against heavy rains as well as rising seawater. An average net profit of about Rs 50,000 to 75,000 was recorded from a 1 ha area. This technology also helps in increasing the soil microbial content and pH. The coconut husk serves as a rich source of potash on decomposition, which was aided by a fortnightly spray of glyricidia liquid manure.

Broad Bed and Furrow System

Vegetable and fodder production have been hampered by a shortage of land after the tsunami and excess rainfall during the rainy season (June–December). Other major problems for vegetable production are extensive damage by giant African snails, bacterial wilt, and water shortages. Broad bed and furrow (BBF) is a technique for growing vegetables and fodder in the midst of rice fields while managing salinity and harvesting water in furrows for dry season vegetable production. It involves the use of alternating broad beds (4 m wide, 1 m high) and furrows (6 m wide, 1 m deep) to provide drainage for vegetables and standing water for rice. The BBF system permits fish rearing in the furrows and fodder crops on the beds, both of which help to include animal components in the agricultural system. Net returns of Rs 62,000/ha were obtained in the first year. In the second year, income of Rs 117,000/ha was recorded from sale of vegetables, rice, and fish. Due to the initial cost of BBF, the return in the first year was low. Cropping intensity and cultivated land utilization index (CLUI) were 100% and 0.38, respectively, before the tsunami and almost zero afterward. However, after this intervention, cropping intensity increased to 300% in beds and 200% in furrows, and the CLUI was 0.78. Moreover, the harvested water in the furrows was available for irrigation during the dry season. The income from the intervention was much higher due to the high value of vegetables during the monsoon season.

Brackish-Water Based Integrated Farming System

Affected land was also converted to brackish-water aquaculture ponds using spillways to regulate the entry of seawater. Along the dyke were planted crops such as spinach, amaranth, okra, bitter gourd, bottle gourd, and pumpkin (Figure 12). Sweet potatoes were also planted along the slopes of the dykes. Plantation crops of coconut, banana, and morinda have been planted. Fodder slips of hybrid napier and para grass were planted along the sides of the ponds. Apart from the income from fish, the crops on the embankments yielded an additional initial income of Rs 2000 from fruits and vegetables in one year. The native fodder on the inner and outer slopes of the embankments was identified as a variety of buffalo grass whose palatability and nutrient analysis suited it for feeding to cattle and goats. This intervention produced a considerable increase in income from fields that were almost completely destroyed by the tsunami. Morinda and coconut crops on the embankments will provide long-term income.

Situation II: Temporary Submergence

Assessment of Soil and Water

The pH of surface soil (0–15 cm) under situation III varied between 4.7 and 6.8, and ECe ranged from 7.2 to 22.9 dS m^{-1}, which indicates that the tsunami caused severe changes in pH and soluble salt content. Sampling revealed that in all soil series, the surface soil had become saline while the subsurface soil (15–30 cm) had smaller amounts of soluble salts, clearly indicating that seawater intrusion during the tsunami did not affect the subsurface soil. Distance from the seashore and inherent soil salinity may also account for part of the variation in soluble salt concentration in different locations.

Surface Soils

In the tsunami-affected areas, soil pH (6.93) was slightly higher than in unaffected areas (6.35). Coastal areas were mildly alkaline to slightly acidic and became more strongly acidic away from the coast. Among the three soil series studied, Dhanikhari soils, which are developed on coastal marshes and are strongly acidic, became neutral to alkaline after the tsunami. EC increased in the tsunami-affected areas (17.89 dS m^{-1}), with greater variability (S.D. = 6.31), than unaffected areas (5.27 dS m^{-1}). Dhanikhari series was found to have the greatest variability (6.68–33.2 dS m^{-1}) of the three series studied. ECe was higher in affected areas of Wandoor and Dhanikhari series soils, which might be influenced by the duration of flood, soil texture, drainage, and other factors. The correlation (r = 0.173) between the spatial distribution of ECe and the duration of flood was not significant, but in gently sloping to flat lands toward the coast, ECe increased with duration of flood.

Sodium adsorption ratio (SAR), a measure of the relationship between soluble sodium and divalent cations (calcium + magnesium) in soil, indicates the degree of soil deterioration. SAR was 2.69 in the unaffected areas and 19.14 in the affected areas. Among the three soil series studied, Dhanikhari had the highest SAR values (6.48–48.18), followed by Wandoor and School line. There was no significant pattern in the spatial distribution of SAR in the affected areas. The excessive concentrations of sodium in the soil may create sodicity problems leading to structural deterioration and poor infiltration.

Subsurface soils

Soil samples were collected from different depths (0–25, 25–45, 45–60 cm) and analyzed for pH, ECe, and SAR in affected and unaffected areas. In all the soil series, the soil pH increased from surface (0–25 cm) to subsurface (45–60 cm) levels in both affected and unaffected areas. The soil pH was acidic (0–60 cm) in all three soil series from unaffected areas. However, neutral to slightly alkaline pH was observed in the tsunami-affected areas of School line soils at 45–60 cm depth. In general, surface soils had higher ECe than subsurface soils, except unaffected School line soils, where ECe was higher in the subsurface. The vertical distribution of pH and ECe indicated that the Dhanikhari series is a potential acid saline soil. This has a profound influence on the availability of nutrients at the root zone and the distribution of microflora and microfauna in the soil profile.

Total dissolved solids (TDS) were higher in the surface soils of the Dhanikhari series than in the Wandoor and School line, due to its finer soil texture that affects the rate of infiltration. Sodium toxicity to plants was severe, and the effects of Na on soil pH and structure were significant. In tsunami-affected soils, SAR increased and varied significantly at the surface soils of the three series. Wandoor soils recorded the highest SAR of all, and this higher sodium content might underlie the impeded drainage conditions after the tsunami.

After one rainy season in situation III areas, there was appreciable reduction in soluble cation and anion concentrations in all soil series, which in turn resulted in reduced ECe values.

After two rainy seasons, surface soil ECe ranged from 0.6 to 5.9 dS m^{-1}, and the subsurface soil ECe ranged from 0.4 to 5.3 dS m^{-1}. The soil pH was also approaching the pre-tsunami level in most cases. After two rainy seasons, in most places it was below 2 dS m^{-1}. Hence, agricultural lands in this situation can be easily reclaimed by high annual rainfall that can effectively leach out the accumulated salts.

Technological Interventions for Productivity Enhancement

Natural resources were not damaged significantly temporary submergence; hence, interventions were made to increase productivity to compensate for losses in other situations. These are described in this section.

Impact of Tsunami on Rice Yield

In South Andaman, traditional rice varieties (C 14-8) are very common and high-yield varieties (HYV) (BTS-24; Sumathi; CSR7-1) occupy nearly 20% of the area planted to rice (Balakrishnana et al., 2006). Grains of the variety C 14-8 present at the time of the tsunami were collected and analyzed for various quality parameters. Grains that were submerged in seawater became softer in consistency and had cooking times up to 15 minutes shorter than the control rice. There was no significant difference in yield between traditional varieties and HYV before the tsunami; however, traditional varieties had higher variability and lower yield than HYV in the affected areas. This indicates that HYV adapted better than the traditional varieties in the affected areas. Rice yield was 59% of that in unaffected areas where the tsunami damage was estimated to be severe after one rainy season. Reduction of 37% was observed in areas considered moderately affected. The higher standard deviation (0.44) for moderately affected areas indicates that localized distribution of salts causes a wide variation in rice crop performance in these areas. Hence, the spatial variability of reduction in rice yield seems to be correlated with the spatial pattern of SAR and ECe in the tsunami-affected areas.

Mat Nursery and System of Rice Intensification

The mat nursery technique was demonstrated in the adopted villages (figure 13) for the first time in the Andaman and Nicobar Islands. Various paddy varieties (Taichung-sen-Yu and Quing Livan No. 1 in normal soil, BTS 24, SR 26B, and CST 7-1 in problem soil) were raised in a flat field as a field demonstration for the benefit of the farmers. The System of Rice Intensification (SRI) was applied under this project using Taichung-sen-Yu, Milyang 55, BTS 24, and Nanjing varieties. The critical stage is the first 20 days after transplanting, when seedlings are vulnerable to damage by continuous rainfall. The mat nursery technique yielded a savings of Rs 1600/ha in field preparation and seed costs compared to conventional nursery preparation. The SRI method produced significantly higher yields (3.95 t/ha) than conventional planting methods (2.00 t/ha).

Crop Diversification

Crop diversification with vegetable and fruit crops was the main technological intervention in the affected villages. Vegetables like spinach, coriander, chillies, capsicum, and French beans were introduced in the appropriate seasons using varieties that had already been developed and screened in research farms. These varieties performed well in the farmers’ fields (Figure 14) with the proper management practices and organic substitution of nutrients.

Freshwater Pond Based Integrated Farming System

Existing freshwater ponds were augmented by others constructed by the government for tsunami rehabilitation. An integrated farming system was adopted to fully utilize this resource. Pond embankments were used effectively to grow crops like coconut, arecanut, banana, and papaya along with vegetables like pumpkin, bitter gourd, and others (Figure 15). Fodder crops, whose scarcity was a major constraint in the milk production system, were introduced on the inner and outer slopes, which also protected the ponds against erosion. Poultry was introduced as an additional income source over the ponds, and droppings were utilized as the manure source for crop plants. It is evident from Fig. 4 that income from the land area in situation III increased significantly from Rs 12,860 to Rs 31,280 in one year from a 1500 m^2 pond.

Participatory Water Resource Development

Irrigation facilities are a major constraint in island agriculture. With this in view, water resources were developed using a combination of recharge structures and open dug wells. A series of gabion structures were emplaced across a stream to enhance groundwater recharge, and open dug wells 2 m in diameter were dug along the stream to harvest the recharged water. To involve stakeholders in water resource development and management, a Water Users Association was formed by farmers with active support of the research team. The purpose of the association was to involve farmers in creation and management of the irrigation facilities, inculcating a sense of ownership of the assets created (Srivastava et al., 2009 a). The association was registered with the registrar under the Societies Act. The association performed the following activities:

- Farmers participated in the creation and management of their irrigation facilities, along with other interventions undertaken by the Central Agricultural Research Institute (CARI).
- Members participated in the bidding, and the contract for ring well, gabion construction, and tank construction was won and carried out by the association with community participation.
- Seedlings of vegetables were raised by youth members in the community nursery and distributed to other members and other farmers of nearby villages, generating revenue of Rs 500/month.
- The youth wing of the association volunteered for agricultural activities in the village, for example, sharing of labour charges among themselves.
- The concept of selling produce to a middleman was abolished; one member of the association now sells the association's whole output directly to retailers.
- After three years of persuasion and motivation by the project intervention in the village, the unemployed youths of Manjeri formed a self-help group under the umbrella of the Water Users Association.

Impact of Water Resources Development

Crop diversification was introduced using high-value and nutritious vegetables and fruits and applying scientific methods such as composting technologies, and using pesticides after irrigation facilities were developed. The area under cultivation before the tsunami during the dry season was 5 ha (29%) out of 17 ha available to the association. This area increased to 12.5 ha (71%) after creation of water resources (Srivastava et al., 2007, 2009 b).

Conclusion

The interventions changed the entire socio-economic setting of the village. The technologies introduced have spread. The nutritional status of the adopted village was also improved (Srivastava et al, 2009 c). The experience leads to the following conclusions:

- The soils of the affected land area became saline due to intrusion of seawater; these salts are leached by rain and the soil returned to pre-tsunami status without the need to apply any amendments. However, reclamation can be hastened by strengthening bunds for storing rainwater.
- It was possible to restore agricultural livelihoods with suitable technological interventions compatible with the farming system.
- Where cultivated land was lost (situation I), the farming livelihood could be restored through introduction of livestock based systems. Suitable measures should be taken to introduce quality livestock and improve productivity of existing livestock through better management practices.
- For situation II (partial submergence), the productivity of available natural resources can be restored by arresting seawater intrusion using sea dykes and self-operated sluice gates.
- Interventions and management practices developed for natural resources in situation III (temporary submergence) can lead to enhanced production and productivity that compensate for land lost to permanent inundation.
- The integrated agricultural technological intervention model applied in the Andaman Islands after the 2004 tsunami can be used to manage natural resources and agricultural livelihoods after similar kinds of disasters.

The impact of interventions was recognized by Government of India and it was included in 101 success stories selected from all over India depicted in Coffee Table Book of Ministry of Agriculture & Cooperation of Government of India (Srivastava et al., 2009 d).

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