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Environmental Change Resilience in Agriculture through Farm Diversification

T.P. SWARNAM*, A. VELMURUGAN, N. RAVISANKAR, I. JAISANKAR AND A.K. SINGH

ICAR-Central Island Agricultural Research Institute, Port Blair
ICAR-Indian Institute of Farming System Research, Meerut
email: swarna_8@yahoo.com

ABSTRACT

A study was carried out to assess the diversification of existing agricultural system in the islands using diversity indices and its effect on resilience to environmental changes. It revealed that diversity was high in homestead IFS while it was low for vegetable and arecanut systems. In integrated and diverse systems biotic barriers were created against pest and diseases leading to suppression whereas in other systems the incidence was high. Although vegetable and arecanut based systems exhibited higher value diversity due to market demand but their species diversity and adjustability was low. Because of these reasons, the homestead IFS and coconut based diverse systems were denoted as high to moderately resilient to environmental changes while rice and vegetable exhibited low resilience.

Key words *agricultural diversity, climate change, flexibility, tropical islands*

Managed ecosystems often fail to respond adequately to external changes and pressures due to several inherent weaknesses. This led to focused research on ecological diversity, regime shifts, and resilience (Folke *et al.,* 2004). Although the concept of building resilience has been widely studied in a broad range of ecosystems (Chapin *et al.,* 2004), this idea has not been well studied in agro-ecosystem which is very important to sustain the productivity and livelihood security.

With greater climate variability, shifting temperature and precipitation patterns, and other global change components, it is expected that a range of crop and ecosystem responses will affect integral agricultural processes. Such effects include changes in nutrient cycling and soil moisture, as well as shifts in pest occurrences and plant diseases, all of which will greatly influence food production and food security (Fuhrer, 2003; Jones and Thornton, 2003). Therefore, development of resilient agricultural systems has become an essential aspect of research and developmental activities to infuse stability to the food production systems and sustaining the benefits of other ecosystem services (Altieri, 1999).

This is more pertinent to Andaman and Nicobar Islands where most of the population are small to marginal farmers (Swarnam *et al.,* 2015). In addition, sea level rise and tsunamis are greater threat to the coastal communities which also impact the agro-ecosystem productivity mainly through salinization and waterlogging. For these compelling reasons it is utmost essential to assess the existing systems and infuse resilient agricultural practices using rational, affordable strategies.

In agricultural systems, biodiversity provides the link between stress and resilience and is vital for ecosystems to function and provide its services (Heal, 2000). There can be enormous diversity within different agricultural systems, and diversification can occur in many forms and over different scales. However, tools for its measurements and quantifications are lacking to make any meaningful comparison across time and space. Therefore, in this study, the diversity of different agricultural systems in Andaman and Nicobar islands were measured as index, evaluated and discussed. The benefits of such diversification with reference to its resilience capacity to the environmental changes were also analysed to fully recognize the multi-functions of agro-biodiversity and its upscaling.

MATERIALS AND METHODS

Study area

The Andaman and Nicobar group of Islands lie in the Bay of Bengal (6-14^0 N latitude; 92-94^0 E longitude) 1200 km east of main land India. The islands experience tropical humid climate because of their location in equatorial zone surrounded by Andaman Sea and Bay of Bengal. The mean annual temperature ranges from 23 to 30° C. The total annual rainfall is high ranging from 3000 to 3200 mm each year. The archipelago is divided, geographically, into five groups of islands, namely North Andaman, Middle Andaman, South Andaman, Car Nicobar, and Nancowry. Due to heavy concentrated rainfall in a short span, flat topography, low infiltration rate and lack of proper drainage most of the cultivated fields are deeply waterlogged limiting the cultivation of high yielding varieties of rice and mono cropping of tall *indica* rice varieties in *wet season.* During dry season, acute shortage of irrigation water along with the presence of brackish water table at a shallow depth compelled the farmers to keep their land fallow. Only at higher elevation with some water source summer vegetables are grown. In Nicobar group of islands coconut is the most dominant crop while tubers and other minor vegetables are maintained in the homegardens or village garden. In general, Forest (87%), homegarden (4.6%) and rice fields (1.3%) cover around 93% of the total geographical area, and are the three major land uses in the islands (DES, 2001).

Data collection and analysis

The data was collected during the farming system characterization survey carriedout by sample survey method throughout Andaman and Nicobar islands. Stratified random sampling procedure was followed to collect the required information. A total of 250 farm fields were characterised covering all the tehsil and major habited islands of Andaman and Nicobar islands. The observational units were 1.0 acre field while the homestead garden at Nicobar islands varied from 0.12 to 0.25 acre. There were 8 different systems such as coconut based, vegetable based,

Table 1. Diversification of different systems as observed in the islands

Sl. No	Nature of system	Location	Diversification			
			Varietal	Crop rotation	Inter-cropping	Farming system
1	Coconut based (C-SA) Occasional inputs, minimum tillage,	S. Andaman	0.8	0.2	0.6	0.5
2	Vegetable based (V-SA) Intensive, high inputs	S. Andaman	1.0	0.9	0.9	0.7
3	Coconut based (C-Nic) No input, zero tillage	Car Nicobar	0.4	0.2	0.5	0.9
4	Homestead IFS (HS-Nic) Low input, minimum tillage	Car Nicobar	1.5	1.2	1.0	1.2
5	Plantation based (P-N) Minimum tillage, no inputs	Nancowry	0.4	0.2	0.5	0.7
6	Coconut mixed (C-HB) No inputs, minimum tillage	Harminder bay	0.6	0.4	0.5	0.8
7	Arecanut (A-LA) Minimum tillage, high inputs	L. Andaman	0.4	0.2	0.3	0.6
8	Rice based (R-NA) Minimum tillage, low inputs	N. Andaman	0.0	0.0	0.0	0.0

coconut (no input) based, homestead IFS, plantation based (no input), coconut mixed (low input), arecanut based and rice based (traditional method) in the study area. The data was grouped into the relevant system and descriptive statistical tools were used to analyse them.

Diversification may be of on-farm and off-farm diversification. The on-farm diversification occurs when more species, different crops, cropping systems, plant varieties or animal breeds, are added to a given farm or farming community. Non-farm diversification may occur when taking up non farm activities or processing of farm products.

· The on-farm diversifications at different systems were measured qualitatively in an increasing scale as poor (0), good (1) and best (2). This was carried out at each site to know about the varietal, crop rotation, intercropping and farming system diversification with reference to rice monocropping assigned as poor. The average value for each system with reference to different diversity parameters were calculated as,

Diversity of a parameter = $Dp = \frac{S_{p1}+S_{p2} \dots +S_{pn}}{N}$

where, Dp is the diversity of a parameter, $S_{p1}+S_{p2}\dots+S_{pn}$ are value for a particular system in a diversity parameter at different sites and N is the number of observations for a particular system for a diversity parameter. In the present study there were 8 systems ($S_1\dots S_8$) and four diversity parameters ($p_1\dots p_4$)

The diversity assessment at farm scale level was done using Simpson's diversity index (Simpson, 1949; Kumar et al., 1994) that is defined as,

Diversity Index $(D.I) = 1 - \sum_{i=1}^{s}(ni/N)$

where S is the number of species or activities that are present, n_i (for i = 1 to S) is the area devoted to the i^{th} species or activity or income of the i^{th} activity , and N (= Sum of n_i) is the total area across all the activities or total farm income. For a farm with only one species or activity with no diversity, diversity index (DI) is zero. As farm diversity increases, DI approaches unity.

Pest and disease incidence and effect of moisture stress during dry season on different crops of the farm were also qualitatively recorded as sensitive (0), moderate effect (1), less sensitive (2) so as to assess the effectiveness of diversification and resilience of the system.

RESULTS AND DISCUSSION

Diversification

The degree of complexity involved in increasing agro-biodiversity to infuse resilience against environmental changes and enhance food and nutritional security ranges from diversifying varieties within a monoculture to landscape level diversification including non-crop and perennial vegetation. The details of such diversification recorded in Andaman and Nicobar Islands are presented in Table 1.

The crop diversification can be achieved at genetic level or species level. In the valley and coastal areas of Andaman Islands, long duration, photosensitive rice variety (C14-8) is mostly grown during monsoon season and land is left fallow in the subsequent season. As a result the crop and other diversity are very low. In coconut based system, particularly new farms, two to three varieties are grown. In most of the old plantations tall varieties are maintained. In contrast, several new varieties are grown in the vegetable system due to higher yield. However, the value is very

Table 2. Diversification in agricultural systems and the potential benefits under climate change conditions

Sl.No.	Type of diversification	Nature of diversification	Benefit	Examples
1	Genetic diversity	Different varieties in a monoculture (rice, coconut, arecanut, vegetables)	Increased production stability	salinity & waterlogging tolerant, withstand moisture stress
			Pest & Disease suppression	Reduced the incidence of pest & diseases
2	Structural diversity	Making the crops within the field structurally diverse	Stability to abiotic stress	Different harvesting period reduces total failure due to moisture stress, unseasonal rainfall and lodging
			Pest & Disease suppression	Reduces Gundy bug, sucking pest and bacterial blight
3	Crop rotations	Temporal diversity and soil biodiversity	Increased production stability	Inclusion of short duration pulse, salinity tolerant rice, different vegetables (type)
			Pest & Disease suppression	Inclusion of disease resistant rice, brinjal and pulses
			Climate change buffering	Stress tolerant crops led to increased buffering of crop to moisture stress
4	System (agro-silviculture; horti-silviculture)	Biofence Alley cropping Bioshield	Increased production	Inclusion of multipurpose trees, multi-storey cropping and fodder
			Climate change buffering	Protection against sea level rise and surges
5	Farming system	Diversified components viz. fisheries, livestock, crops,	Increased production stability	Greater stability of production and income
			Climate change buffering	Multiple components led to less failure during sudden environmental changes (moisture stress, cyclone)
6	Crop diversity with non-crop vegetation	Vegetation banks in and alongside crops (homestead IFS, coconut garden in Nicobar)	Pest suppression	Trapping of pest in non-economical crop, hosting of natural enemies of mealy bug and sucking pest
7	Species diversity (polyculture)	Growing more crop species, fishes etc.	Increased production	More production of vegetables and fishes
			Climate change buffering	Land races, local and adapted species can grow under changing conditions
8	Landscape (mixed)	Diversified landscape with multiple ecosystem (different cropping schemes)	Pest suppression	Higher level of natural enemies in fruits and vegetables

high (1.5) for homestead IFS due to mixture of traditional and new varieties and the practice of natural forming by the tribes. Similar is the case for crop rotation and intercropping. In conventional diversified systems crops and livestock co-exist independently from each other and serve primarily to minimize risk and not to recycle resources. In an integrated system, crops and livestock interact to create a synergy, with recycling allowing the maximum use of available resources. In tribal farming system practised in Nicobar, livestock constitute the integral component and play vital role in their socio-economic activities. As a result of this, the farming system diversification is high for homestead based IFS (1.2) followed by coconut based systems (0.9) when compared to the rice monoculture.

Potential of diversified agro-ecosystems

Contemporary knowledge on climate change suggests that it will affect both biotic (pest, pathogens) and abiotic (solar radiation, water, temperature) factors in cropping systems, threatening crop sustainability and production (Lin, 2011). More diverse agro-ecosystems with a broader range of traits and functions will be better able to perform under changing environmental conditions (Altieri, 1999), which is more important given the expected changes to biotic and abiotic conditions in the island ecosystem. The following are a few of the major ways that the greater functional capacity of agro-ecosystem diversity has been found to protect agricultural productivity against environmental change (Table 2).

Table 3. Resilience of different farming systems as measured by stress and diversity indices

Sl. No	Farming system	Reduction in Pest & Disease intensity	Moisture stress adjustability	Species diversity	Value diversity	Resilience environmental changes
1	Coconut based (C-SA)	1.2	1.2	0.23	0.41	Moderate
2	Vegetable based (V-SA)	0.8	0.8	0.58	0.60	Low
3	Coconut based (C-Nic)	1.4	1.2	0.27	0.41	Moderate
4	Homestead IFS (HS-Nic)	1.6	1.3	0.72	0.65	High
5	Plantation based (P-N)	1.4	1.2	0.41	0.48	Moderate
6	Coconut mixed (C-HB)	1.3	1.3	0.27	0.52	Moderate
7	Arecanut (A-LA)	1.0	0.8	0.19	0.62	Low
8	Rice based (R-NA)	0.9	0.7	0.00	0.02	Low

In agricultural systems herbivorous insects can have significant impacts on plant productivity. Thus, pest suppression is a perennial challenge to farmers which may intensify in the future as changes in climate affect pest ranges and potentially bring new pests into the island agricultural systems. Under island conditions practitioners of natural and integrated farming are able to assist in creating biotic barriers against new and potential pests by increasing the plant diversity of their farms in ways that promote natural enemy abundance. Further, inclusion of trap crop and non-economical crop were found to reduce the pest infestation. In intensive vegetable production systems of South Andaman inclusion of pest and disease resistant varieties with broad genetic base and structural diversity were suitable choice to reduce the pest infestations. However, the diversity of crop species in an agro-ecosystem has a much less predictable effect on microbial pathogens compared with crop pests, as microclimatic conditions play an important role in the development and severity of a disease (Matson et al., 1997; Fuhrer, 2003). As a results microclimate modification methods such as reduced tillage, organic manure addition, and drainage improvements in coconut, arecanut, rice and vegetables have reduced the severity of diseases.

Studies have shown that crop yields under island conditions are quite sensitive to changes in precipitation and temperature, especially during flower and fruit development stages (Velmurugan *et al*., 2015). Temperature maximums and minimums, as well as seasonal shifts, can have large effects on crop growth and production. Greater variability of precipitation, including flooding, drought, and more extreme rainfall events, has affected food security in many parts of the world (Parry et al., 2005). One of the best available choices is the inclusion of agroforestry systems which protect crops from extreme events (e.g. Depression and tropical storms). In Andaman and Nicobar islands biofence, alley cropping and other agroforestry measures have proved to instill environment change resilient to island farming systems.

Resilience of farming system

With greater plant species richness and diversity in spatial and temporal distribution of crops, diversified agro-ecosystems mimic natural systems more than rice monocropping (Table 3). Consequently it was able to maintain a greater diversity of natural enemies of crop pests. Besides inclusion of agroforestry components by the tribal farmers of Nicobar islands could able to achieve long-term pest suppression for agricultural systems and by building up a bank of potential natural enemies for any future pest outbreaks in the system. It is a reliable measure until otherwise altered by human interference. In homestead system due to diversity of crop, its moisture use pattern, and duration it has higher adjustability and less pest incidence. In contrast vegetable and rice system were less adjustable to moisture stress and experienced high incidence of pest due to favourable environment for pest population to build up. Although vegetable and arecanut based system exhibited higher value diversity due to market demand but their species diversity and adjustability were low. Because of these reasons, the homestead IFS and other diverse systems were denoted as high to moderately resilient to environmental changes while rice and vegetable exhibited low resilience.

Although many recognized that diversity can improve the resilience of agricultural systems to environmental change, the adoption of increased diversification has been slow for a number of reasons. Primarily economic policy incentives for the production of monoculture row crops under intensive management have outweighed the perceived incentives to implement diversified farming systems, although this may change as climatic variations increase. Therefore, while introducing any changes in the existing farming system should essentially consider its relative advantage and suitability to the agro-ecological conditions of the island.

CONCLUSION

The study illustrates that the agricultural biodiversity is enhanced significantly by diversification at different scales in an integrated faming system approach that results in resilience to agriculture besides food and nutritional security. Systems with high value diversity such as arecanut, vegetables are less resilient while homestead IFS and livestock integrated coconut farming are stable and exhibited resilient to environmental changes. In addition, other climate resilient strategies such as water harvesting and its judicious use, salinity and soil fertility management and crop planning will strongly support the resilient capacity of the faming system. The diversified farm also support biodiversity conservation at farm level together with proper utilization of land races and traditional varieties it will lead to resilient and sustainable island farming systems.

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