Participatory research and development to evaluate *Pongamia* seed cake as source of plant nutrient in integrated watershed management

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Abstract

The semi-arid tropics (SAT) is spread largely in Asia and Africa and is the home for one billion people of which 350 million are poor. Soils in the SAT are inherently low in fertility and prone to severe degradation; the current crop productivity is around 1 t ha^{-1}. Integrated watershed management approach is adopted to improve the natural resource base as well as to enhance the agricultural productivity on sustainable basis. For enhancing the impact through greater adoption of improved technologies participatory research and development (PRD) tool is quite effective. In the integrated watershed development approach PRD is adopted to a large extent. The PRD approach involves diagnosis, planning, experimentation and evaluation. All the steps are done in a participatory mode.

The PRD approach is adapted to improve livelihoods of the tribals in Andhra Pradesh, India using *Pongamia*-based livelihood activities. Detailed process of research and development is studied and the results are described. Institutional development particularly formation of self-help groups (SHGs) at the village level and capacity building helped substantially to improve livelihoods. The local institutions like village organizations and SHGs helped to mobilize financial flow with lower transaction costs. Other activities like awareness building along with capacity building initiatives have increased as a spill over. The various development initiatives in Powerguda village that enabled the community to embark on various environmental and natural resources protection measures along with livelihood options such as *Pongamia* plantations, oil extraction and sale of seed cake as source of plant nutrients, protection of forest and growing nurseries, provided not only additional income but also environmental services for the community. Agriculture is a main source of livelihood in both the study villages (Powerguda and Kistapur); however, with capacity building and higher collective action in Powerguda and through watershed development initiatives substantial gains in agriculture production was achieved and incomes have increased over the past five years substantially. The farmers could move up the poverty line within a short period of time. The better livelihood opportunities in both the villages have changed the purchasing power of households resulting in higher investment in agriculture and allied activities. New employment opportunities and diversification of income along with supplementary irrigation have substantially reduced the vulnerability to drought and brought substantial multifold impacts on the livelihoods.

The activities such as growing nursery, collecting seeds and extracting oil in the village provide employment and livelihood during the off-season in the village, which not only bring additional income but also gender equity, as the wage rates related to *Pongamia* seed collection are same for both male and female laborers. Through development of social and human capital along with financial capital the community is able to undertake initiatives to enhance the natural capital also. As development of one capital interlinks with the other capitals the overall development of community could be achieved through *Pongamia* initiative. In addition, the byproduct of oil extraction, ie, oil cake, is evaluated as a source of plant nutrient for enhancing the productivity of rainfed systems. The seed oil cake contained around 4% N in addition to other major, secondary and micronutrients needed for plant growth. Participatory evaluation of seed cake application to soybean and cotton showed increase in crop yields significantly (32–101%) when applied alone or in combination with mineral N fertilizers. In terms of N equivalence, the crop yields were more than N applied particularly in case of cotton indicating that the increased yields were due to not only N effect but also other beneficial properties such as carbon as well as other micro and macronutrient contents of the seed cake. The PRD approach was found quite effective to explain the benefits of the new technology.

Introduction

The leading challenge for ICRISAT is to address agricultural uncertainty for 560 million poor in the semi-arid tropics (SAT) spread over 55 countries. The SAT is dominated by parched lands, degraded natural resources, low agricultural productivity, intense population pressure and stubborn poverty. Torrential downpours during rainy season, poor infrastructure and low investments for soil, water and crop management further aggravate the situation. More than 70% of the population in India depends on agriculture for their livelihood. Farm households in the SAT with low agricultural productivity (0.8 to 1.5 t ha^{-1}) due to low water-use efficiency have no option but to continue drawing their livelihood from rainy season single crop grown on degraded lands with credit from usurious moneylenders. This is exacerbated by the lack of employment opportunities and inadequate agri-support services. In these villages, seasonal migration of male adults to augment income was common. Farm households are trapped in the vicious cycle/nexus of drought, land degradation and poverty. Familiar stories and scenes of this nature are common in the SAT villages not only of India but also of Vietnam, Thailand, China and other parts of Asia and Africa.

The interlocking constraints faced by farm households prompted the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) to launch its learnings of 25 years of strategic and on-farm development research using CGIAR priorities as the guidepost. ICRISAT-led participatory watershed management through consortium and convergence, espouses the Integrated Genetic Natural Resources Management (IGNRM) approach. The landscape/watershed approach adopted benchmark sites to represent agroecoregions in SAT Asia. This approach revolves around the four Es (empowerment, equity, efficiency and environment), which are addressed by adopting the strategies prescribed by the four Cs (consortium, cooperation, convergence and capacity building). The consortium strategy brings together institutions from the scientific, non-government, government and farmers' group for knowledge management. Cooperation enjoins all stakeholders to harness the power of collective actions. Capacity building engages in empowerment for sustainability. Convergence allows integration and negotiation of ideas among actors (Wani et al. 2008).

The potential of rainfed agriculture in the tropics is held back mainly due to low adoption of suitable soil, water and nutrient management (SWNM) options and poor availability of seeds of high-yielding improved varieties resulting in low rainwater-use efficiency. Along with the deficiency of macronutrients such as nitrogen (N), phosphorus (P) and potassium (K), most tropical soils are found severely deficient in micro and secondary nutrients. During baseline characterization of the nucleus and satellite watersheds in different states of India we observed that 80 to 100% of the farmers' fields were deficient not only in macronutrients such as N and P but also micronutrients such as zinc (Zn), boron (B) and secondary nutrients like sulfur (S) (Rego et al. 2005, Sahrawat et al. 2007). The results in Table 1 reveal that in Andhra Pradesh the situation is similar to rainfed farmers' fields in other states of India.

Widespread deficiency of micronutrients in Indian tropics

Deficiency of micro and secondary nutrients in irrigated areas in India is well recorded and suitable management options are being adopted by the farmers. However, in subsistence rainfed areas where productivity is low such widespread deficiency of micro and secondary nutrients was not expected. Deficiencies of these nutrients are widespread because farmers earlier used to apply organic manures to their fields; however, with the increasing demand for the organics and the shortage in supply, economic compulsions do not permit small and marginal farmers to apply organic manures to rainfed areas. Some of the policies in the country providing subsidy on nitrogenous fertilizers and not on phosphatic fertilizers made farmers to shift from single super phosphate to diammonium phosphate (DAP) and in the process S was eliminated.

Table 1. Soil analysis across three districts in Andhra Pradesh, India, 2002–03.

District	No. of farmers	Total N (ppm)	Available P (ppm)	Available K (ppm)	OC (%)	B (ppm)	S (ppm)	Zn (ppm)
Mahabubnagar	282	342	8.6	1.04	0.34	0.15	4.5	0.52
% deficient fields		100	37	7	59	98	89	83
Nalgonda	176	410	7.6	130	0.39	0.21	4.4	0.4
% deficient fields		100	39	3	80	99	89	94
Kurnool	223	295	7.9	127	0.32	0.27	4.4	0.4
% deficient fields		100	40	8	91	92	88	81

There is an urgent need to develop suitable integrated nutrient management (INM) practices to enhance the productivity of rainfed systems to sustain development as well as maintain the quality of natural resources (Wani 1997). The INM strategy includes maintenance or adjustment of soil fertility and plant nutrient supply to sustain the desired level of crop productivity. It is a holistic system approach focusing on the cropping and farming system rather than on individual crop and individual field. Further it does not preclude the use of mineral fertilizers. It relies heavily on optimal use of renewable nutrient sources such as biological nitrogen fixation (BNF) and organic manures and minimal or need-based use of mineral fertilizers. Green manure is used to improve soil productivity. Despite the advantages attributed to green manuring, it has not gained the acceptance it deserves for several reasons: (i) it gives no immediate income; (ii) its effects in tropical soils are short-lived; (iii) it does not fit into the farmers' mixed cropping system; and (iv) most importantly, farmers do not like to sacrifice a growing season without tangible economic benefit for improving soil health. The alternatives such as growing N-fixing shrubs on property bunds and addition of lopping to the farm and bringing in organic matter from N-fixing trees grown on wastelands or common lands are preferred by the farmers.

The problem

Pongamia and *Jatropha* plants are drought tolerant and not browsed by animals. These species are biodiesel candidate crops that produce seeds containing 30–39% non-edible oil. *Pongamia*, an N-fixing tree which is grown in forests and as avenue plantation is found suitable for rehabilitating degraded lands as well as for using oil as biodiesel after esterification. In this study the results of *Pongamia*-based development in rural India are discussed. The activities such as growing nursery, collecting seeds and extracting oil in the village provide employment and livelihood during the off-season in the village which not only bring additional income but also gender equity, as the wage rates related to *Pongamia* seed collection are same for male and female laborers. Through development of social and human capital along with financial capital the community is able to undertake initiatives to enhance the natural capital also. As development of one capital interlinks with the other capitals the overall development of the community could be achieved through *Pongamia* initiative. In addition, the byproduct of oil extraction, ie, the cake, is evaluated as a source of plant nutrient for enhancing the productivity of rainfed systems.

Adilabad in Andhra Pradesh is largely a tribal district endowed with good forests and tribals have access (usufruct rights) to a large natural resource base. *Pongamia* is of Indian origin and is widely grown in these forests. Recently, *Pongamia* seed oil is being used as biodiesel and in Powerguda village, women self-help groups (SHGs) are collectively operating the oil extraction unit (D'Silva et al. 2004). In Kistapur, water-energy initiative has been launched wherein farmers share the water drawn through pump sets using decentrally produced power using *Pongamia* oil.

The participatory watershed management approach adopts the participatory research and development (PRD) conceptual framework. In the PRD framework, the four important phases are participatory diagnosis of the problem, identification and evaluation of the solutions, monitoring and evaluation and refinement of the approach. This approach is quite new and has found enhanced adoption of the technologies by the farmers as they are the part of the whole process.

Conceptual framework

- Livelihood system framework emphasizes the need for poor people to manage their five capitals: natural resource base, information and knowledge, physical assets, credit flow and decision making in governance.
- Poor and marginalized groups (ethno groups) are often faced with limited resources or access to resources.
- Biophysical assets include lands with low fertility and other natural endowments.
- Human capital in terms of literacy, skills, knowledge and information for these groups is low.
- Opportunities to improve livelihood could be enhanced by utilizing the waste transforming into value added resource.
- Through participatory demonstration the value of *Pongamia* cake in INM and livelihood opportunities can be improved and diversified.
- This would result in increased crop yields, conversion of waste into resource, reduction in input costs and provision of diversified livelihood options for the poor and landless groups.

Problems/constraints. The problems faced by the farmers are listed.

- Absolute poverty
- Water scarcity

- Low erratic rainfall
- Low fertility
- High land degradation
- Low access to knowledge/information
- Poor infrastructure
- Limited institutional support services
- Marginalized from public governance

Intervention

Use of *Pongamia* cake, a byproduct after oil extraction was initiated to enhance soil fertility and rainwater-use efficiency in local farming systems for improving livelihoods.

Outputs. The expected outcomes of the intervention are listed.

- Increased crop yields
- Increased income from sale of *Pongamia* cake
- Conversion of waste into resource
- Reduction in input costs
- Provision of diversified livelihood options for the poor and landless

Research methodology

To undertake this project we adopted participatory integrated watershed management approach as the umbrella project. As a part of the INM strategy we selected two micro-watersheds (Powerguda and Kistapur) where the watershed project is operated. As the main source of organic matter is *Pongamia,* watersheds nearer to the common forests where people have access to collect the necessary material are selected for the purpose of this study. Already, the villagers have been extracting oil from the *Pongamia* seeds through a collective action in Powerguda. Seed cake, a byproduct from the oil extraction plant, is not being used currently. Detailed analysis of the seed cake indicated that it is a rich source of plant nutrients along with organic carbon which is badly needed for maintaining productivity of tropical soils.

Materials and methods

Livelihood analysis. For the purpose of taking up livelihood analysis in two villages, viz, Powerguda and Kistapur, five capital assets (physical, human, financial, social and natural) were assessed using primary and secondary data. Primary data was collected by adopting rapid and participatory methods using appropriate analysis tools (DFID 2000). During data collection for the present study every key indicator of different capital assets were evaluated at village level with the participation of the community and weighted on fixed marked methods according to their importance.

The rapid methods referred to primary data, rapid case studies, key informants interviews and focused group discussion (FGD) (Fig. 1) while participatory methods used an extractive mode of in-depth studies. In the process of Stage I of rapid methods the secondary data that related to different kinds of capital assets were collected from different departments of Government agencies such as Mandal Revenue Office, Primary Health Centre, Primary Veterinary Centre, Regional Marketing

Figure 1. Focus group discussion with the women farmers in Powerguda and Kistapur, Adilabad district, Andhra Pradesh.

Centre, Regional Forest Centre (Van Sanrakshan Samiti), Regional VELUGU (District Poverty Initiative Programme) Office working on poverty alleviation, Village Panchayat, other NGOs and development societies, etc.

In Stage II of participatory approach, about 60 to 78% of sample households in the village participated in FGDs. The key issues discussed were the status of the five capitals and employment activities in the village. These exercises were continued for three to four days in each of the selected villages and different activities such as collective mapping of the local area, developing a time line, ranking the importance of problems inside a matrix, wealth ranking, transect walks, producing seasonality calendar, etc were undertaken. The process of participatory rural appraisal (PRA) was very successful for putting together the information within limited time. Further, the group gathering was stratified into different categories on the basis of gender and landholding to assess the information about vulnerability context relating to poorest of the poor farmers in the village. Various key indicators were used to access the different kinds of capital assets and these indicators were ranked into very good, good, moderate, poor and severe based on the availability and accessibility by the farmers in each of the villages, viz, Powerguda and Kistapur. The key indicators were again scored on fixed mark, ie, 45 for very good, 30 for good, 15 for moderate, 8 for poor and 2 for severe. Most of the indicators were weighted in the ascending order of changes from lower to higher values but few are in descending order. For instance, if water table increased substantially then it ranked very good and scored 45 marks but if migration was higher then it ranked very poor and scored only 2 marks. Care was taken to involve both male and female members in eliciting the information. The simple method of percentage was used to access the present status of livelihood capital assets in both the villages. In terms of measurement the total scored value of each indicator was averaged to avoid any complexities of double scoring because of higher or lesser number of indicators in different capital assets. And the percentage of average value of each indicator to total average value of all indicators was calculated. The value in percentage of each capital asset depicts the present status of livelihood capital in the form of pentagon in both the villages. In each village the source of livelihood focused mainly on seven core activities, ie, agriculture (farming), labor wages in agriculture and non-agriculture activities, selling of non-timber forest produce, nursery of *Pongamia* and *Jatropha* plants (also collection of seeds and extracting oil from seeds), trading, construction works and livestock. The data were derived from on-farm and off-farm activities based on the village-level study. The concept of rural income-generating activities and different kinds of dependencies were elaborated broadly to the farmers before commencing the study of different kinds of livelihood sources of the villagers in each village. The farmers including men and women were asked directly and indirectly their sources of income from different activities in particular months of a year. Impact is measured based on the information collected from the sample households and their mutual observations on different indicators of particular capital assets. Accordingly the indicators were categorized under different capital assets such as financial, physical, natural, social and human capital. Based on the PRA and detailed survey results, livelihoods activity calendar was prepared for Powerguda and Kistapur villages.

Participatory on-farm trials. The results of livelihood analysis were discussed in community meeting for validation. The field research was undertaken based on the following principles:

- Knowledge-based entry point for building rapport with the community.
- Empowerment of farmers through PRD.
- Seeing is believing – snow ball effect.
- Farmers to become change agents.

Focus group discussion: Taking lead from the earlier work on *Pongamia* plantations with the farmers in Powerguda and Kistapur villages, FGDs were held with the farmers. Farmers perceive *Pongamia* leaves as a good source of plant nutrients and traditionally the leaves are used for green manuring. The seed cake, which is a byproduct from the oil extraction plant operated in Powerguda village, was analyzed for its nutrient content and the results were discussed with the farmers. The farmers were informed that it is a valuable product for improving the soil quality and crop yields. Eight voluntary farmers in Powerguda were selected for participatory evaluation of *Pongamia* seed cake as source of plant nutrients using cotton (*Gossypium* sp) and soybean (*Glycine max*) crops. In Powerguda, the holdings are large but the land is highly undulating with light soils in the upper ridge and black soils in the lower areas. Farmers prefer light soil for soybean and deep black soils (Vertisols) for cotton. The soils of Kistapur are medium deep Vertisols and most of the farmers have opted for soybean in place of cotton due to losses incurred in the previous year. Soybean is considered a safe crop and more beneficial than cotton but it is a new crop in this area and seed treatment with *Rhizobium* is not practiced. Ten voluntary farmers were selected for participatory evaluation effect of micronutrients on crop yields along with recommended fertilizer doses.

Soil analysis: During the FGDs with the farmers, soil analysis as an important test to assess the soil health was explained using the simile of human health. Results of soil analysis from other villages in Andhra Pradesh were used to build the scenarios of increased crop production and increasing net incomes with suitable nutrient amendments. The voluntarily selected farmers were trained for collecting the representative soil samples from their fields. Along with the technicians the farmers collected the soil samples from their fields in both the villages. Soil samples were analyzed at ICRISAT in the laboratory. An analysis of soil indicated a large-scale deficiency of S, Zn and B. The results of soil analysis were discussed with the farmers and explained to them with appropriate examples. During the discussions with the farmers, soil analysis results were used as an entry point to build rapport with the community and as a tool to build their knowledge about soil health. Farmers realized that application of these nutrients was appropriate for increasing the crop yields. Based on the willingness of the farmers, treatments using *Pongamia* seed cake as well as micronutrients were discussed and identified with guided discussions. In case of soybean, besides nutrient application, treatment of seed with *Rhizobium* was discussed and promoted. In Powerguda and Kistapur, participatory trials with soybean and cotton crops were planned and conducted by the farmers. In Powerguda eight farmers (four each with soybean and cotton) evaluated the *Pongamia* seed cake with and without micronutrient treatments. For assessing the economic viability for evaluating seed cake as source of plant nutrient, treatments of chemical fertilizers were also included along with the combination of seed cake and chemical fertilizer. In Kistapur village ten farmers evaluated the use of micronutrients. Farmers were encouraged to participate in record keeping and observation.

Results and discussion

Sources of livelihoods. During the FGDs with people in both the villages, 37 respondents in Kistapur and 18 respondents in Powerguda were investigated for detailed data collection. Seven core sources of livelihoods were identified. Most of the farmers basically depend on agriculture, ie, 75% in Kistapur and 57.2% in Powerguda for their livelihoods. The second source of livelihoods in both the villages was agricultural labor wages (about 17% in Powerguda and 8% in Kistapur). Non-agricultural wage labor was ranked third as a source of livelihood in Kistapur village with 4.8% and ranked 6 in Powerguda with 2.8% (Fig. 2).

Non-timber forest produce is the third source of livelihood for 11.7% of the population in Powerguda and fourth in Kistapur (4.8%). This is because of increased awareness and empowerment of the community; people are collecting *Pongamia* seeds from the forest trees and extracting oil for commercial purpose. They are not only able to make use of the forest produce for their livelihoods but are adding value to the raw produce and increasing their incomes. Realizing the benefits, the community has collectively undertaken large plantation

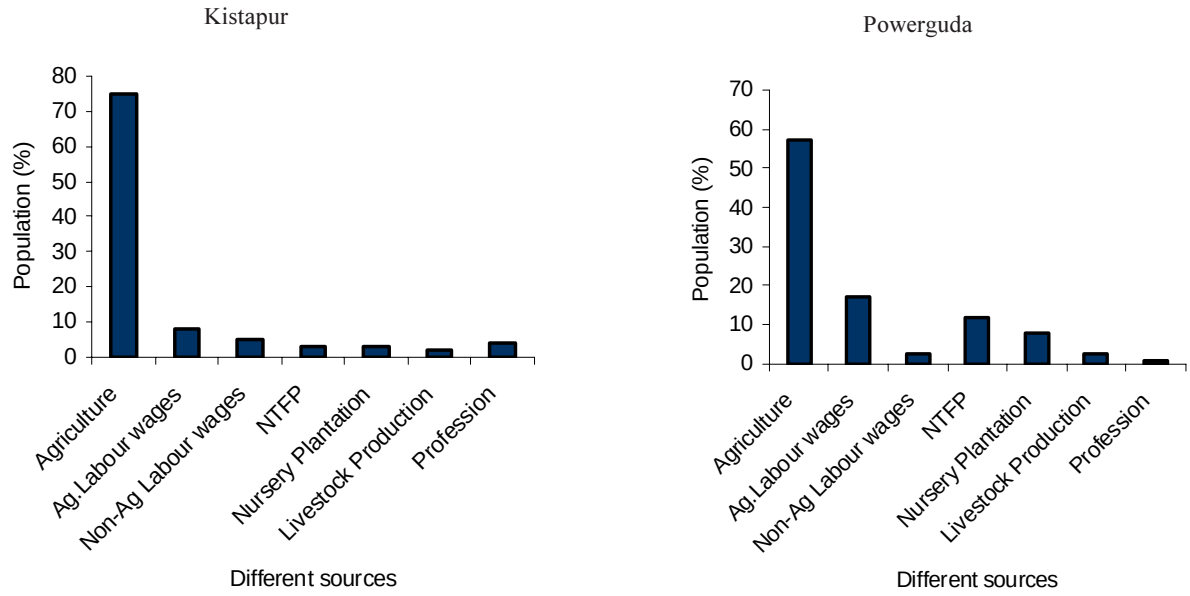

Figure 2. Different sources of livelihoods in Kistapur and Powerguda in Adilabad district, Andhra Pradesh.

of *Pongamia* trees (10,000) in the forest. The related activity with *Pongamia* trees such as nursery raising is undertaken by women SHGs and they earn additional income by selling excess *Pongamia* plants to neighboring villages.

The SHG is also running an oil-extracting plant in Powerguda provided by Integrated Tribal Development Agency (ITDA). The extraction unit is also a source of income particularly for women (Fig. 3). The byproduct of oil extraction from *Pongamia* seeds is the seed cake, which is a good organic source of plant nutrient. The sale of seed cake provides additional income and when it is applied in the fields (reduced investment), crop yields increased resulting in higher net profits. Nursery raising is ranked the fifth important source of livelihood in Kistapur by 3% while it ranked fourth in Powerguda by 77.9% (Fig. 4). Livestock production ranked sixth in Kistapur and fifth in Powerguda as a source of livelihood. Overall the productivity of milching animals is low in both the villages. Even children less than five years of age are not getting adequate milk for their consumption. In Kistapur village about 3.99% of population depends on non-skilled profession while in Powerguda it was only 0.56%.

***Pongamia* nursery supporting livelihoods during off-season.** Nurseries of *Pongamia* and *Jatropha* plants were introduced to farmers for increasing their income and to support livelihoods during a short period of time, especially off-season. The community invested Rs 30,000 received from the World Bank as part of environmental service payment in *Pongamia* nursery raising. The money was used for enhancing environmental services and also earning livelihoods on sustainable basis (D'Silva et al. 2004). In Powerguda, a group of 10 female members, who are engaged for approximately two months (60 days) for raising nursery of *Pongamia* plants including marketing and transportation assert that the nursery raising of these plants has become the best source of income by selling the plants, each for Rs 3. They are able to save about Rs 1200 to Rs 1500 per member per season. In the village there are two agencies, viz, forest protection committee (Van Sanrakshan Samiti) and ITDA, which are the main buyers of these plants. Furthermore, these plants are planted in the surrounding forest areas and in 3–5 years the villagers would get additional income through collection of seeds and extracting oil from *Pongamia* seeds to be sold as biodiesel. The byproduct, ie, seed cake, would help in improving soil fertility, thus cutting the cost of cultivation and enhancing incomes through increased agricultural productivity sustainably.

Seasonal migration from village stopped with development activities. One oil extracting machine was installed in Powerguda village with the initial cost of Rs 375,000 and women SHG members are engaged to generate additional income by selling *Pongamia* oil at the rate of Rs 30 per liter. In the process most of the farmers especially women are getting additional employment opportunities (65 days) in the form of collecting and crushing the seeds. Women are collecting the *Pongamia* seeds from the forest area. The extraction of 4 kg seeds of *Pongamia* provide at least 1 kg of biodiesel and about 3 kg of seed cake. The cake is used as a good source of nutrient-rich organic material for enhancing crop productivity and soil fertility.

In Powerguda, neither men nor women go outside the village in search of livelihoods even during summer, which is a lean period for agricultural activities. They are mainly engaged in different income-generating activities such as extracting oil from *Pongamia* seeds, collection and selling of non-timber forest produce, and nursery

Figure 3. *Pongamia* seed oil extraction unit in Powerguda.

Figure 4. Women engaged in raising *Pongamia* nursery in Powerguda.

raising in addition to agriculture and development activities.

In Kistapur village there is no female migration in any season but approximately 167 male members are migrating seasonally in March, April and May for generating additional income to support their livelihoods.

The case of Powerguda, where the community is involved in diversifying livelihoods using value addition approach for the products from the existing natural resources, is an excellent example of collective action and empowerment in a bid to overcome poverty. Other development activities have provided sufficient employment and income-generating opportunities for the rural poor to escape poverty and not to migrate in desperation because of sustainable use of natural resources such as forest produce and value addition through capacity building and collective action.

Seasonal calendar. Seasonal calendar for various livelihood activities was drawn by the farmers encouraged by the facilitator. It has given some useful insights. Generally agricultural operations are concentrated during April, May, June, August, November and December and men are actively engaged in them. Women take up activities like nursery raising and collection of *Pongamia* seed complementing the income generation for the family during lean season. Diversified livelihood options have provided work throughout the year for the poor households and put a virtual stop to distressed migration.

Gender analysis was undertaken using the seasonal calendar along with the responses of FGDs (Fig. 5). It is clearly evident that in nine months of the year, women's workload is heavier than men in Powerguda and Kistapur village. The number of remunerative days is lower for women throughout the year in both the villages and non-remunerative working days are always higher for women. This implies that women partake in activities for earning livelihood for the family while continuing to do the domestic work. But when the two villages are compared female farmers are engaged in remunerative activities for more days in Powerguda than in Kistapur. *Pongamia* seed collection remunerates women on par with men and since it is a dominant source of livelihood in Powerguda it explains for the higher number of remunerative days in Powerguda as compared to Kistapur.

Building of social and financial capital in the villages – Easy credit availability promotes diversified livelihood opportunities. The SHGs were formed in both the villages through different programs of the government such as watershed development, VELUGU, etc aiming to help poorest of the poor farmers especially women to sit together and solve their common problems themselves and also boost small savings among its members. The savings through SHGs are cost effective and have efficient delivery and recovery mechanisms for small credit to its members. Availability of credit at the doorstep through micro-financing with marginal (12% per annum) transaction cost is quite popular and effective. In Kistapur village there are seven SHGs. The members of these groups were imparted training on nursery raising of *Pongamia* and *Jatropha* seedlings to generate additional income for their livelihoods during off-season.

In Powerguda village there are three groups but the ratio of number of SHG members to total population is high. The existing groups are availing all facilities similar to other groups in surrounding villages besides extra income with more employment days in a year through extracting biodiesel from *Jatropha* and *Pongamia* seeds. There is an increase in the value of assets of the SHG group members along with small ruminants and consumer durables from Rs 2150 to Rs 3110 per household registering an increase of 44.65% on becoming a member of a SHG. The linkage between commercial bank and SHGs were found very strong and it is striking to note that the per capita savings in each group increased at galloping speed within three years. For instance, the Laxmi Swayam Sahai group was created with Rs 360 on 17 December 2002 and at present the saving of this group stands at Rs 6780. Similar trend of savings with small differences was observed in case of other groups during the period of survey in the village. However, the savings of groups in Powerguda village are comparatively less except Durga Devi group.

The village organization (VO) which is the Federation of SHGs in both the villages has its own account in the bank and at the time of study, the VO of Kistapur had Rs 222,520 while that of Powerguda village had Rs 290,000. The VO usually provides loan to the members of SHGs at the rate of 1% per month for maximum 6 months repayment period. In 2009, the VO of Kistapur village lent Rs 280,000 at 1% per month to members of the group and Rs 50,000 to other villagers, who are not members of the group while Rs 30,000 was given to the Mandal Mahila Samakhya, the Federation of VOs at a higher administrative unit (ie, 'mandal'), at similar rate of interest for maximum 6 months. Apart from these the meeting of VO is conducted once a month and it is essential for all members of the group to participate in the meeting to solve the problems associated with groups. Unresolved problems are forwarded to the Mandal Mahila Samakhya, which meets at Mandal level.

This networking of women into groups has not only led to enhanced livelihood opportunities and capacity building but also contributed to the empowerment of women. Today the SHG leader of Powerguda can speak to any official or visitor dauntlessly which was not the

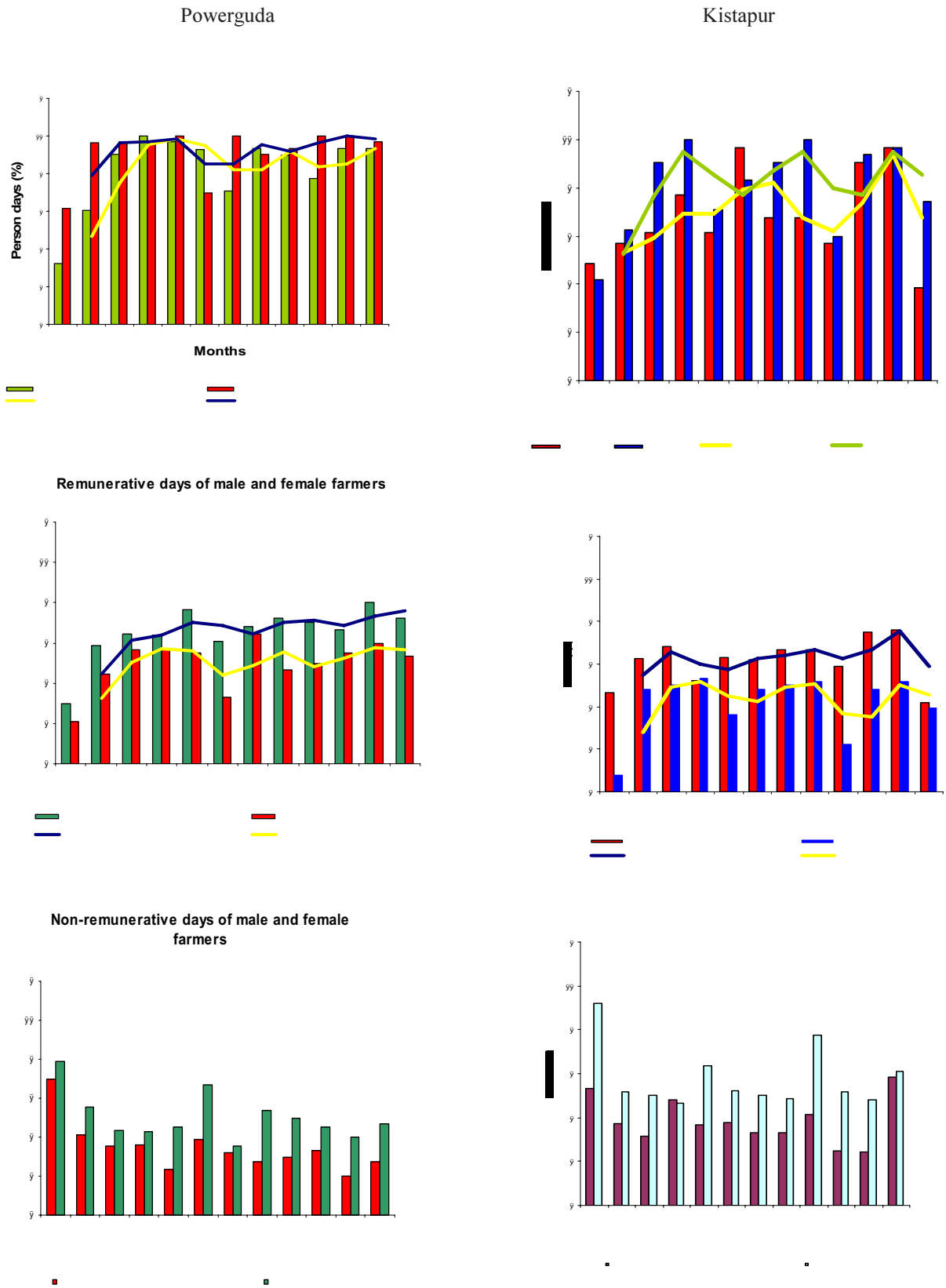

Figure 5. Gender analysis in Powerguda and Kistapur: (a) Working person-days (male/female); (b) Remunerative working days (male/female); and (c) Non-remunerative working days (male/female).

case 5 years earlier in the tribal hamlet. Similarly, even ordinary women SHG members stated that "Earlier when any official or stranger came to our village we would simply get into the house. However, that was the case earlier, now we inquire the purpose of their visit to Powerguda."

The capital assets of livelihoods. The status of livelihoods in each village summarized in terms of pentagon depicts the five capital assets: natural, human, social, physical and financial by calculating percentages of key indicators (Fig. 6). Although the villages are situated in the same agroecoregion and the geographical characters of villages are also similar to a large extent yet significant differences were observed between the two villages. In Powerguda, natural capital is substantial (29.46%). Within financial capital income from agriculture (26.33%), collection of non-timber forest produce (17.34%) is observed. Since there are only 30 households in this village, human and physical capitals are small. However, social capital is comparable to any other village in the area with all women organized into three groups involving in thrift and credit activity along with income-generating livelihood activities. In Kistapur, the pentagon is almost symmetrical due to the access to the highway and good number of households (150) in the village with seven SHGs.

Availability of employment for labor in the village is good and migration to suburban areas is absent or minimal in Powerguda. The score of health status in Kistapur was found higher (22.96%) than in Powerguda village (19.61%); also the education status was found greater (15.31%) in the village, which could be due to the location of Kistapur village on the National Highway and good access to medical and educational services.

The score for access to drinking water in Kistapur and Powerguda villages is similar. Both villages are totally electrified and the consumption of energy is also satisfactory but Powerguda village has a higher score (24.82%) than Kistapur village (16.76%). In both the villages most of the houses are *pucca* (built with bricks and cement) under Indira Aawas Yojna scheme of the Government. Both the villages do not have any heavy machines or tools like tractor, thresher and other cultivation equipment but most of the farmers possess good number of small machines and tools. Livestock production in Powerguda as well as in Kistapur is low and except small ruminants the ratio of cattle, buffaloes and goat is very less resulting in low milk production. The forest area in Kistapur village covers about 375.2 ha of land while in Powerguda village it is only 123.2 ha. However, the per capita availability of forest area in Powerguda village is higher (0.68 ha) than that in Kistapur village (0.60 ha). The score for social capital in Powerguda village is slightly higher (20.54%) than that in Kistapur village (18.94%). Kistapur is a heterogenous community and as such groupism exists whereas in Powerguda farmers are homogenous and united. Although the number of SHGs is higher in Kistapur village, the number of groups per member is higher in Powerguda village.

Seed oil cake: a source of plant nutrients and income for the SHGs. Oil cake, a non-edible byproduct after extraction of oil, appears to be a very attractive proposition as it contains all the macro and micronutrients and it is an excellent organic fertilizer unlike inorganic fertilizers that supply only few nutrients (D'Silva et al. 2004).

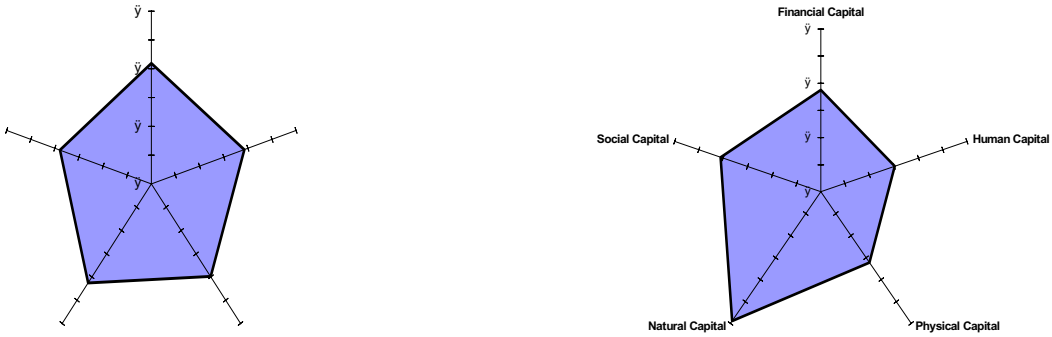

Figure 6. Livelihood pentagons depicting the five capital assets (%) in Powerguda and Kistapur villages in Adilabad district of Andhra Pradesh.

About 4 kg seed of *Pongamia* or *Jatropha* give 3 kg of cake. The cake is mostly used for fertilizing plantation or commercial crops. An analysis of cake of *Pongamia* and *Jatropha* indicated presence of all the essential elements required for plant growth and was particularly found to be rich in N and S. This oil cake is also a good source of income for the SHGs as it is a good organic source of plant nutrients as well as organic matter necessary for enhancing agricultural productivity.

Participatory evaluation of oil cake for increasing crop productivity. Farmers' participatory trials were conducted to evaluate the effect of oil cake application on soybean and cotton yields. Out of eight farmers' trials, five trials for each crop were selected after conducting the *Gram Sabha* (village meeting) to explain the importance of the seed oil cake as a valuable source of plant nutrients as well as much needed organic matter for their soils. Farmers were trained in collecting representative soil sample from their fields and the collected samples were analyzed for their fertility status. The soil analysis revealed that these soils were not only deficient in N and P but also were severely deficient in B, Zn and S. Each farmer served as a replication and four treatments were used, viz, farmers' practice (75 kg DAP ha^{-1}); *Pongamia* seed cake at 500 kg ha^{-1}; recommended fertilizer (100 kg DAP ha^{-1}); and recommended fertilizer at 50% (50 kg DAP ha^{-1}) and *Pongamia* seed cake at 50% (250 kg ha^{-1}) for soybean. Normal weed management and interculturing operations were undertaken during the season. During the season, farmers along with the researchers monitored the crops and crop growth observations were recorded. Farmers' day was conducted prior to harvesting of the crop and the trial farmers explained the treatment details and crop performance to other farmers (Table 2).

Results of farmer participatory trials with soybean showed that grain yield was significantly increased by 32% due to application of 500 kg seed oil cake over the farmers' practice with 75 kg DAP ha^{-1}. Similarly, recommended dose of fertilizer as well as 50% recommended fertilizer and 50% seed cake increased grain yields by 49% and 41% respectively (Table 2). Using farmers' practice as a check, we calculated N and P fertilizer equivalence for different treatments (Table 2). The results showed that the benefits due to seed cake application in terms of increased grain yield were similar to the N applied or many times higher for applied P. The N recovery being almost 100% indicated that the increase in grain yield was not only due to N and P content in the seed cake but also may be due to increased availability of other growth limiting nutrients.

Results of participatory evaluation trials with cotton also showed similar results with application of 3000 kg ha^{-1}

Table 2. Grain yield of soybean grown with mineral N fertilizer and *Pongamia* seed cake in farmers' fields, Powerguda village, Adilabad, rainy season 2005.

Treatment	N applied (kg ha^{-1})	N fertilizer equivalent using FP	P applied (kg ha^{-1})	P fertilizer equivalent using FP	Grain yield[1] (kg ha^{-1})
Farmers' practice (FP) (75 kg DAP ha^{-1})	13.5		34.5		1220
Pongamia seed cake (PC) (500 kg ha^{-1})	21.4	17.8	4.6	45.5	1610 (32)
Recommended fertilizer (RF) (100 kg DAP ha^{-1})	18.0	20.2	46.0	51.6	1830 (49)
RF 50% + PC 50%	19.7	19.1	25.3	48.7	1730 (41)

1. Average of 5 replications; % increase over FP is given in parentheses.

Table 3. Grain yield of cotton grown with mineral N fertilizer and *Pongamia* seed cake in farmers' fields, Powerguda village, Adilabad, rainy season 2005.

Treatment	N applied (kg ha^{-1})	N fertilizer equivalent using FP	P applied (kg ha^{-1})	P fertilizer equivalent using FP	Grain yield[1] (kg ha^{-1})
Farmers' practice (FP) (125 kg DAP and 125 kg urea ha^{-1})	80.0		57.5		890
Pongamia seed cake (PC) (3000 kg ha^{-1})	128.4	160.4	27.6	115.3	1790 (101)
Recommended fertilizer (RF) (200 kg DAP and 200 kg urea ha^{-1})	128.0	95.3	92.0	68.5	1065 (19)
RF 50% + PC 50%	128.2	103.6	59.8	74.5	1160 (30)

1. Average of 5 replications; % increase over FP is given in parentheses.

Pongamia seed cake or 50% seed cake (1500 kg ha^{-1}) plus 50% recommended fertilizer dose (100 kg DAP ha^{-1} and 100 kg urea ha^{-1}). Application of seed cake alone increased cotton yield two-fold (Table 3) which was valued equivalent to 160 kg fertilizer N ha^{-1}. These results are similar to the results with soybean indicating that the increased yields are due to not only N or P application but also other nutrients and soil quality improving factors in the seed cake.

Summary and conclusion

Although the assessment of livelihood assets is a complex task because of identifying and maintaining proper balance between quantitative and qualitative indicators of each capital associated with livelihoods yet the comprehensive study has brought up significant findings.

Emerging outcomes. The research areas are located in rainfed regions, which have erratic rainfall, low rainwater-use efficiency with inherently low crop productivity resulting in poverty and malnutrition. However, the participatory approach of watershed development program improved resilience of livelihood opportunities. The livelihood opportunities in the two micro-watersheds, Powerguda and Kistapur, in the same agroecoregion are distinctly different because of variability in livelihood assets, different levels of interventions and institutional development, and access of different capitals in the villages. In the livelihoods framework, capital assets are strongly interlinked and any change in one capital asset directly influences the magnitude of change in other capitals; therefore, the variability in different capitals governed the livelihood options for the farmers in remote areas. The results show that the sustainable management of natural resources especially bringing in diversified livelihood options such as environmental service, biodiesel production chain, etc, in a remote watershed with poor infrastructure could provide livelihood opportunities in a village (Powerguda) and people need not migrate. However, in Kistapur with better soils and similar rainfall, large numbers of people have to migrate out for livelihoods. The experiences of other watersheds where natural resources were managed properly like Kothapally in Andhra Pradesh also recognize similar paradigms of shifting migration in search of livelihoods. Watershed development played a vital role in both the villages. Institutional development particularly formation of SHGs at the village level and capacity building helped substantially to improve livelihoods. The local institutions like VO and SHGs helped to mobilize financial flow with low transaction costs. Other activities like awareness building along with capacity building initiatives have increased as a spill over. The impact of various development initiatives in Powerguda that enabled the community to embark on various environmental and natural resources protection measures such as *Pongamia* plantations, protection of forest, growing nurseries and oil extraction, provided not only additional income but also environmental services for the community. Agriculture is a main source of livelihood in both the villages; however, with capacity building and higher collective action in Powerguda and through watershed development initiatives substantial gains in agricultural production was achieved and incomes have increased over the past five years substantially. The community empowerment and diffusion of new source of livelihood opportunities in the village of Powerguda, *Pongamia* nursery raising, oil extraction and sale of seed cake as source of plant nutrients have enhanced the ambit of livelihoods of people in the village. The farmers could move up the poverty line within a short period of time. The better livelihoods opportunities in both the villages have changed the purchasing power of households resulting in higher investment in agriculture and allied activities. New employment opportunities and diversification of income along with supplementary irrigation have substantially reduced the vulnerability of drought and brought substantial multifold impacts on the livelihoods.

Livelihood opportunities. The interventions of watershed development program in the selected villages have provided alternative opportunities of livelihoods to the farmers. In Powerguda village the extraction and marketing of oil from *Jatropha* and *Pongamia* seeds has provided tangible benefits to the farmers by selling oil at the rate of Rs 30 per liter. The farmers especially women are getting additional employment opportunities for about 65 days through collection of seed from the forest and crushing in the machine. The oil extracting mill has become an important source of income for farmers to support their livelihoods. For instance, farmers are earning Rs 2 kg^{-1} *Pongamia* seed crushed in the village. The nursery of *Pongamia* and *Jatropha* has become a new diversified livelihood opportunity to the women in the village. The nursery has a capacity for 20,000 saplings of which 10,000 are planted on community land and the rest are sold to nearby villages and to the forest department. Average family income has substantially increased from Rs 15,677 in 1999–2000 to Rs 27,821 in 2002–03, which represents about 77% over three years, or 5% per annum (D'Silva et al. 2004). These practices are novel approaches to eradicate poverty and enhance livelihood opportunities of the farmers. The pathway of these developments can be projected as a strategic model for the development of other rural areas in the country.

Gender dimension. The diversified livelihood opportunities have increased the remunerative days for women. This is a desirable trend but it has also increased the workload.

Lessons to take forward

- Government interventions/development initiatives have enhanced the natural, physical and financial capital but coordinated efforts need to be focused on social capital and human capital. Development and empowerment need to be focused on parity.
- Gender balance needs to be established with improved technologies and interventions to reduce drudgery such as cake pounding machine, improved nursery raising techniques, etc, along with impetus to female literacy, primary enrollment and health services.
- Community-managed watershed development and forestry programs need to be encouraged.
- Rainwater-use efficiency should be taken up in agricultural development along with diversified cropping systems.
- Networking of farmers through SHGs (thrift and credit – women SHGs) should be promoted to make agriculture more remunerative.
- Work with labor wages parity should be encouraged such as *Pongamia* seed collection, etc.
- Livelihood activities aimed at non-working days need to be promoted; for example, May and October, which are *Pongamia* seed collection periods, show no non-working days for women in Powerguda.
- Efficient use of byproduct to enhance incomes from agriculture need to be further explored and strengthened.

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