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Soil Health: Issues and Concerns - A Review

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ABSTRACT

This paper brings out the importance of soil fertility management (SFM) with respect to agricultural production and livelihood contribution to the rural people. It looks into the farmers' own knowledge systems and how they contribute to the sustainable soil fertility management. The review clearly brings to the fore the fact that livestock is crucial to maintain soil fertility, supply of draught power, food for the family and to increase the agricultural productivity, especially in dry lands. It examines the role of social, economic, ecological and livelihood factors in soil fertility management. Soil fertility management options available to farmers are being undermined by government policies that primarily focus on chemical fertiliser-based strategies. Based on the review it can be argued that the agriculture should aim at the use of organic inputs for supply of nutrients. The paper suggests that government policies related to soil fertility management be more enabling interms of creating conditions for the use of locally available resources, skills and knowledge.

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I. Introduction

"Soil fertility is the soil's ability to produce and reproduce. It is the aggregate status of a soil consequent on its physical, chemical and biological well-being." where as soil productivity, is "The overall productive status of a soil arising from all aspects of its quality and status, such as its physical and structural condition as well as its chemical content." (Stocking and Murnaghan, 2001). This definition clearly spells out that the practices to be used for enhancing soil fertility have to take care of overall health of soils. But in reality, the chemical fertilizers which are based on external resources do not meet most of these requirements except providing nutrients to plants in inorganic form. They do not help for the long term sustainability of the soil health (GoI, 2008b). A most recent report of FAO says that 20 percent of cultivable lands in the world are losing fertility impacting 150 crore people (one fourth of worlds' population). However, the major section of government, policy makers, agricultural scientists and agricultural extension departments still think that chemical fertilizer application is the primary way of improving our crop and food production. Majority of these sections seldom think of what is happening to long term health of soil and its capacity to produce sustainably.

Soil health, the very basis for crop production, assumes greater significance from the livelihood view point of millions of farmers world over, more so in the Indian context. However, most research studies on soil fertility management in India do not go beyond the technical aspects, such as the quantity of inorganic fertilizer needed for various crops in different agro-climatic conditions, ignoring ecological, cultural, livelihood and socio-economic dimensions associated with soil fertility management. With this context in view, the present paper reviews various issues relating to soil health and the role of soil fertility management in agricultural production with an emphasis on semi-arid conditions. In this paper an attempt has been made to critically review different studies, which have a direct and or indirect bearing on the soil fertility management. This paper is organized into five sections including this, second section takes a look at the economic aspects of Soil fertility management; third section dwells on socio-cultural, institutional and policy aspects, while fourth section focuses on the ecological dimension of soil fertility management followed by concluding observations in the last section.

II. Economic aspects of Soil Fertility Management

a) Livelihoods

Agriculture, animal husbandry and allied activities and non-farm activities including migration, constitute the main sources of living for farmers in the rural areas. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future without undermining the natural resource base. Although different sections of the rural society are dependent on diverse livelihood options, the poor tend to behave in ways different from wealthier households, as they remain constrained by their access to assets besides having to manage trade-offs between different livelihood strategies, diversification, intensification and migration.

Practices which enhance soil fertility contribute significantly to the livelihoods of rural people in various ways (Reddy, 2011a). Sheep penning is a classic example of a symbiotic relationship between pastoralists and farmers and is also one of the examples of how soil nutrients can support livelihoods. Reddy (2010a) reports that shepherds are a source of best quality farm yard manure (FYM). Similarly, ownership of bullocks for ploughing is an important livelihood opportunity for the landless and poor, and can be a crucial factor in determining whether someone is able to lease in or sharecrop land (Adolph and Butterworth, 2002). In Andhra Pradesh, the diversity of cropping pattern is an important livelihood strategy, especially for resource-poor farmers (Poinetti, 2005; Reddy, 2010b).

Trading in FYM is an important livelihood opportunity for many poor families in semi-arid tropics (Butterworth *et al.*, 2003). More importantly, in the presence of welfare programmes of the state, more than 50 percent of the landless households mostly belonging to the Scheduled Caste community, have become cattle owners over the last decade (Adolph and Butterworth, 2002). It is mainly because of this, that the poor and landless are in a strong position to benefit from FYM trade. However, there are also negative aspects associated with such trade. In many cases, FYM sales are a coping strategy to raise cash for vital expenses such as health bills. However, in some cases, pressure is exerted by powerful landowners on small and marginal farmers to sell FYM that they would otherwise use themselves. Infact, increased demand for organic inputs, changes in livestock number and ownership have led to a rapidly expanding market for organic fertilisers (Reddy, 2010b).

Labour is a key component in carrying out all activities related to soil fertility management (Devika, 1993). In fact, such activities require several thousand hours of human labour interms of collecting, processing, transporting and applying leaf litter, livestock manure, compost, green manure, ash, straw, husks, etc. Hence farmers, despite being aware of their poor role in maintaining soil structure, are becoming increasingly dependent on chemical fertilizers as a labour saving device (Reddy, 2010a). Further, labour-intensive SFM practices like green leaf manuring, tank silt application are diminishing due to factors such as non-availability of labour (especially in the case of medium/large farmers), changing cropping patterns and livelihood diversification (Reddy, 2011a). New practices like vermicomposting and agro forestry have emerged due to interventions in the form of developmental projects (Reddy, 2010b). There has been a polarization of soil fertility management practices (Adolph and Butterworth, 2002). The labour component of the SFM activities can be a big positive aspect for inclusion in the Mahatma Gandhi National Rural Employment Guarantee Act (MNREGA) activities (Reddy, 2010a). Investing huge amounts in soil fertility enhancement activities will not only provide livelihoods for people, but also improve the long term health of soils with a definite increase in production and productivity of various food and cash crops in the country. In this way, we can also integrate MNREGA and agriculture, which will be of great help to all categories of farmers.

The poor, it is claimed, will inevitably find it more difficult to respond to the pressures brought about by intensification due to their low resource status (Main, 1995). Intensifying systems that have failed, leading to an increase in soil fertility depletion and increased poverty, have led to either migration or 'urbanization' as people seek alternative livelihoods. Rao (2000) observes that watershed development is a strategy for protecting the livelihoods of people inhabiting fragile ecosystems being exposed to soil erosion and moisture stress. Unfortunately, most agricultural research work and extension agencies focus their activities on chemical fertilisers, which neither offer livelihood opportunities for the poor and landless nor match their SFM needs (Reddy, 2010a; 2011a). Further, inappropriate animal breeding programmes and discrimination against livestock also have contributed to the disappearance of livestock-based livelihoods in AP (Pimbert and Wakeford, 2002). Hence, there is a need to focus on gaining a better understanding of the decision making processes of households in terms of managing and integrating their nutrients within the context of local livelihood strategies.

b) Livestock

Livestock, besides being an integral part of agriculture, have a profound influence on sustainability interms of generating incomes, employment opportunities and organic manure. The quantity and quality of livestock influence soil fertility management both directly and indirectly (Reddy, 2010a). They contribute directly by influencing the availability of organic manure; and indirectly through their influence on household incomes. The integration of livestock and crop production, or mixed farming, allows for the use of animal manure to increase soil fertility (Ranjitha *et al.*, 2004; Reddy, 2011a). Apart from the fact that associated benefits of using manure, in view of relatively high costs of mineral fertilisers, FYM could play a greater role in maintaining soil fertility (Reddy, 2010a; 2010b and 2011a).

The nutrient management system has become more closed in the late twentieth century due to the weakened traditional linkages between forest and livestock (Turton *et al.*, 1997; Sagari, 2004). However, this has, to some extent, been compensated by the use of chemical fertilisers, which have been integrated into the existing nutrient management systems. Intensification of agriculture and changes in livestock population can have a cause-and-effect relationship on each other (Anonymous, undated; Reddy, 2008a). Intensified agriculture generates higher incomes for farmers, which will help them to increase livestock population. Increased livestock population, in turn, will help farmers increase and stabilize their income levels besides yielding higher amounts of manure which can be considered as an input for Integrated Nutrient Management (INM); and it also helps sustain crop productivity and livelihoods.

Studies have found that livestock component of the farming system is crucial to maintaining soil fertility, supply draft power and food (milk, curd and meat etc.) for the family (Reddy, 2001; Reddy, 2010b). But declining fodder and water resources combined with blanket animal-breeding policies, fuel a downward spiral of loss in livestock genetic diversity, draught power, natural fertilisers, livelihoods and household assets (Pimbert and Wakeford, 2002). Poinetti (2006) in her study on seed autonomy with respect to south Indian state of Andhra Pradesh argues for strengthening of diversity based farming systems across the drylands. She concludes that farmers must be ensured of an appropriate access to livestock, organic inputs, bio-pesticides and seeds for dryland crops.

Liyama and *et al.* (2007) have conducted a study on crop-livestock diversification (CLD) patterns in relation to income and manure use in Keiyo district of rift valley province in Kenya. The primary focus of the study was to identify the dominant CLD patterns in the study area; to investigate which CLD patterns are associated with higher income and with more intensive manure use and also to examine the factors which affect a households' decision to adopt better CLD patterns. The study uses four statistical methods namely descriptive statistics, principal component analysis, Ordinary Least

Square (OLS) analysis and ranking using principal component factor score. The study identifies five dominant CLDs out of which a pattern of improved cattle and fruits is found to be associated with higher household incomes and intensive manure use. This combination has been interpreted as integrative crop-livestock intensification pathway, not only welfare enhancing but also environmentally sustainable. The study concludes that it is not the number of animal holdings but the degree of integration between distinctive crop types that determines the intensity of manure use.

Ensuring sustainable intensification and economically profitable integration of crop-livestock farming to meet the welfare and environmental goals of people is of paramount importance. Makinde *et al.* (2007) point out that better utilization of organic manure from livestock has the potential to ensure a sustainable crop-livestock intensification especially for poor agro-pastoralists, as they often cannot afford to buy expensive inorganic fertilizers. Efficiently applied, crop and livestock activities would contribute not only to income generation, but also higher crop productivity and better environmental health through supplying nutrients to soils without relying on external resources.

Of late, livestock economy is changing very rapidly in India. The growth of draught animal stock has slowed down; milch animal stock is growing relatively faster and the proportion of cross breeds among milch animals is growing rapidly (Conroy *et al.*, 2001; Reddy, 2001; Adolph and Butterworth, 2002; Reddy, 2011a). The reasons include a reduction in farm size, increased mechanization, decline in the area of common property resource (CPRs) lands and the changing patterns of labour availability (Conroy *et al.*, 2001; Reddy, 2010a). This has important implications for the availability of manure. Local animal breeds, important for livelihoods and sustainable agriculture should be conserved in- situ by strengthening integrated farming and indigenous systems of land use in which livestock plays a key role in nutrient cycles and the maintenance of soil fertility (Reddy, 2011a). In the *"Prajateerpu"* conducted in Medak district of Andhra Pradesh, the jurors observe that the erosion of livestock biodiversity would increase with the corporate agriculture proposed under vision 2020 (Pimbert and Wakeford, 2002). They specifically call for appropriate training and research as well as for government support to re-introduce livestock.

There is an inadequacy of draught power stock (animal power in particular) across rainfed ecosystems. We also need to identify critical and timely requirements of draught stock in the production systems besides the extended use of the available draught stock during relatively less critical periods. Thus, livestock rearing, being a self-income generating enterprise, helps reduce irregularities and uncertainties in income from farm business (Anonymous, undated; Reddy, 2010a). A combination of agriculture with dairy and poultry farming can fetch small farmers more average net income than other enterprises (Ranjitha *et al.*, 2004; Reddy, 2010b). Therefore, the extension agencies should advise, educate and motivate the small farmers into opting for the above combination on their farms.

In brief, with weakening forest and livestock linkages, the nutrient management system has become closed. Also a reduction in common property resource areas has affected the availability of nutrients. Thus, it is very clear from the review that livestock activity is crucial to maintaining soil fertility, supply of draft power, food for the family and increasing the agricultural productivity in dry lands.

c) Property Rights

Livestock enterprise depends considerably on forests and other Common Property Resources (CPRs) for fodder. The other sources include crop residues, bushes and grasses from own farms and the market. CPRs add between 15 and 23 percent to the poor people's income and thus contributes substantially to improving economic equity at the village level. For small and marginal farm households, between 31 and 42 percent of total own farm inputs are contributed in cash or kind flows from CPRs. Employment generated by CPRs for the poor is higher than on-farm work for public works (Jodha, 1990). Iyengar and Shukla (1999) point out that CPRs constitute 0.1 to 11 percent of consumption expenditure of farm and between one and 22 percent of non-farm households. Chen (1991) reveals that the poor collect over 70 percent of their fuel and 55 percent of fodder from CPRs. Singh *et al.* (1996) find that CPRs contribute about 27 percent of the gross income of the landless and 22 percent of cultivating households. Over 30 million people depend wholly or substantially on non-forest timber products, which are of particular importance in the lean season (Agarwal, 1997).

Reddy (2001) indicates that large farmers prefer community management of grazing lands as they benefit maximum from common grazing, while lower income households plead for privatisation on the ground that the village elite always corner the benefits from community management and that even when commons are auctioned, the revenue generated is not used for fulfilling the needs of the poor directly. Similarly, large farmers arguing for banning small ruminant grazing, goes against the interests of lower size class and landless households.

Pastoral herds now tend to be more restricted in their grazing range, resulting in the "region-wide" over grazing. Crop encroachment, access to market/services and threat of conflict, all serve to reduce the flexibility and mobility that are central to pastoralist strategies for maintaining animal productivity through sustainable rangeland use in semi-arid areas (Steinfeld *et al.*, 1997; Reddy and Praveena, 2011). Farming systems presently rely on nutrients being brought in by cattle grazing on common lands, but these grazing areas are dwindling with additional land being brought under cultivation. If the common grazing lands disappear, the farming systems of some households will be deprived of a major source of additional nutrients (Hilhorst and Muchena, 2000).

A study carried out by Devika (1993) in Nepal, reveals that land tenure determines the level of investment to be made on soil fertility management. Interestingly, the study brings out that sometimes an agreement contains a condition to that effect (between the owner and tenant) that the tenant apply a certain minimum amount of compost to the land. This clearly indicates the importance farmers give to maintaining the long term health of their soils. The study also finds owner cultivators investing most on their lands, applying the maximum amount of compost, green manure, mulch etc. These farmers are most dynamic in experimenting, improving and using the best possible strategies (so far as resources permit) so as to conserve and collect soil and to improve soil structure. They know that they will reap the benefits of such long and short term investments. Tenants, on the other hand, want quick returns from soils they lease in with in a shorter period and hence, chemical fertilizers suit them as they increase crop yields over a shorter span of time. This aspect is consistent with the finding of Scoones and Toulmin (1999) in respect of Africa.

III Socio-Cultural, Institutional and Policy Aspects.

a) Socio-Cultural Practices: Local Knowledge

In addition to technical factors, there are many social issues, which significantly affect SFM. Infact, it is these factors, which influence the adoption of various soil fertility management methods under the rainfed farming systems. A brief review of the studies, which look into the role of social factors in SFM, is presented below.

It is very hard to predict, as to how a community gets affected from changes in demand for nutrients. The extent to which the changing nutrient demand due to intensive cropping and nutrient management affects a community depends on the structure and integration of its members, and their degree of acceptance of this new approach (Anonymous, undated). Diversity is an important feature of farming systems at all scales. At the household level, farmers manage this diversity through different land-use practices, choice of crop and input levels (Poinetti and Reddy, 2002; Poinetti, 2005;

Reddy, 2009). Diversity at the village level landscape is exploited through use, for example, of low-lying areas, for moisture-loving crops, uplands for millets and groundnuts, and gravelly slopes for grazing and woodlands. The farmers value such diversity as it provides greater protection against the risk of crop failures (Scoones, 2001; Reddy, 2010a; 2011a). Besides, farmers' socio-economic status influences their access to productive assets, which affect the nutrient balance of their farms (Hilhorst and Muchena, 2000; Reddy, 2010b; Reddy, 2011a). Besides capital, the capacity of a household to keep cattle is closely linked to the number of adult family members engaged in farming (Adolph and Butterworth, 2002; Reddy, 2010a). Devika (1993) in her study on indigenous Soil Management in the Hills of Nepal finds that the access to three major inputs namely material, labour and cash influences soil fertility management options available to the farmer.

A study conducted by Farouque and Tekeya (2008) covering 494 families spread across 8 villages in 4 districts of Bangladesh in the year 2006 tries to determine the extent of Integrated Soil Fertility (ISF) and Nutrient Management (NM) practices used by farmers. The research sites were selected based on the history of stagnation or a reduction in crop yields in the recent years and the gradual decline of soil fertility. A four- point summated rating scale was used to study the seven soil fertility management practices recommended for examination by an expert panel from the soil science department of Bangladesh Agricultural University, for collecting data concerning farmers' use of organic manures for crop production, seven sources of manure such as cow dung, farm yard manure, crop residues, green manure, poultry faeces, oil cake and ash- were identified and the respondents were asked to describe the extent to which such manures were used. The study finds that 61 percent of the farmers using different soil fertility management techniques either rarely or occasionally, while 22 per cent of them not adopting any type of soil fertility management. Only 17 per cent of the total farmers practise soil fertility management techniques regularly. It could be clearly seen in the study that the medium and large farmers practiced soil fertility management techniques more frequently than resource-poor farmers. Similarly out of the seven organic manure sources studied, resource poor farmers use only those sources of organic manure that do not require cash to acquire.

Several traditional soil nutrient management techniques practiced by farmers since long have been abandoned in the recent past (Acharya *et al*., 2001; Reddy 2010b, 2011a). The documentation of indigenous technical knowledge in Andhra Pradesh shows how rich has been the time-tested traditional knowledge interms of protecting of agricultural crops and livestock (Majhi, 2008). There is now a growing concern towards blending traditional wisdom with modern technologies for maintaining harmony with nature. Researchers like Kerr (1996) and Kerr and Sanghi (1992) draw attention to the fact that farmers are aware of the need for soil conservation and fertility and that they have adopted indigenous methods for soil conservation. Interestingly, farmers' soil fertility management practices which are based on long experience and a rich knowledge of the localy-specific conditions and constraints are alive and vibrant (Butterworth *et al.*, 2003; Reddy 2010c; 2011a). These practices are dynamic in that they change over time, with changes in input availability and cost (especially labour) and continuous innovations being made by farmers. Thus, there is a need for looking at indigenous knowledge systems in their entirety given their centrality to the food futures of the human billions in the SAT region (Adolph and Butterworth, 2002).

Farmers follow certain criteria for classifying soils, such as their workability, inherent fertility, suitability for certain crops, responsiveness to particular inputs and water-holding capacity (Reddy, Scoones, 2001; 2008b). Singh and Singh (2005) in a study carried out in Sonapur and Hamirpur villages of Azamgarh district of Uttar pradesh for understanding the wisdom of farmers, draw attention to the criteria developed by them for soil classification and fertility management based on research methodology of agro-ecosystem analysis, resource flow maps, Participatory Rural Appraisal (PRA), focused group discussions and transect walk. The study reveals that in addition to physical parameters, farmers also consider *soil biology* - the presence of several organisms such as snails, crab, spider, earthworm, red ants, centipedes and termites, for determining soil fertility.

Contrary to this, in the mainstream scientific circles, issues related to soil quality and fertility are dealt with as an extremely specialised knowledge, which borders on mystification of this knowledge (Adolph and Butterworth, 2002). It is also a common belief that unless farmers get their soils tested in the scientific laboratories and understand their strengths and deficiencies in "scientific" terms, what they know about soils is not a viable knowledge. This, ofcourse is a highly questionable proposition. Several studies (Butterwoth *et al.*, 2003; Singh and Singh 2005; Reddy, 2008b; 2010a) recognise that farmers have a wealth of knowledge about soils, their nutritional strengths and deficiencies. It is only that the terms and definitions they use are very different from the ones used by the formal science. What is probably needed from the community of formal science and formal research is simplifying the meanings of these terms and translate them into a language they understand.

The small farms are able to apply manure at rates that meet the nutritional requirements of continuous cropping without having to purchase expensive fertilisers. Small farms can apply four times more cattle manure than large farms (Lekasi *et al.*, 1999; Reddy, 2011a). Resource- rich households having access to FYM or mineral fertilisers have a completely different nutrient budget as compared to resource- poor households who tend to apply the largest amounts of manure per unit area. Manjunath *et al.* (1998) indicate that a majority of the farmers perceive the practice of green manuring and composting as being simple, free and useful. Voluntary organizations working with farmers recognize both formal scientific knowledge and farmers' knowledge, which is often based upon good science. These organizations deal with SFM issues based on the felt needs of farmers (Adolph and Butterworth, 2002).

Of late, the farming community has come to realize that fertilizers give only a short-lived boost to plant growth and FYM is widely superior and long lasting with a positive impact on soil properties; hence, FYM is ranked highest and chemical fertilisers lowest in most matrix ranking exercises (Adolph and Butterworth, 2002). Similarly, considering the quality and importance of improving the fertility status of soil, the farmers of Azamgarh district of Uttar Pradesh rank different practices in the following order : sheep, goat and cow penning; crop rotation; application of crop residue and green manuring; fallowing; incorporation of weeds and manuring and tillage practices (Singh and Singh, 2005). Crop rotation, agro forestry and intercropping are the most widely practised of the low external input practices in the rural Kenyan districts of Nyandarua and Mumias (Yengoh and Svensson, 2008). The study also finds that it is possible to increase the level of soil nitrogen through the use of low external input practices.

Land values are mainly determined by land quality, including soil depth and the level of soil fertility (Shiferaw *et al.*, 2003; Reddy, 2011a). Neither the perceived risk of soil degradation nor the private and public investments have a significant influence on land values. Land/soil quality is an important factor when it comes to private lands and farmers maintain soil quality as much as possible with the help of crop rotation and input mix (Reddy, 2001; Reddy 2010a). Besides, farmers are aware of their soil quality and the likely impact of the current cropping and input use patterns on soil quality. Recent shifts in the cropping pattern towards input-intensive crops may have an adverse impact on the methods used for maintaining soil quality. Medium class farmers appear to be more vulnerable to this trend (Reddy, 2011a). Since medium size class farmers have a limited access to irrigation they tend to maximise profits per unit of water available. While large farmers target overall profit maximization, marginal and small farmers do not enjoy much of a choice as they hardly have access to water (Reddy, 2001).

The influence of farm size on fertiliser use is linked to income constraints (Clay *et al.*, 1995) whereas, Singh and Desai (1991) argue that there is no influence of farm size on fertiliser use at the household and plot levels. This is contrary to the findings of Sharma (2012) who points out that small and marginal farmers tend to use twice the quantity of fertilisers per hectare of land as compared to large farmers in India. Singh and Singh (2005) based on their study with reference to Uttar Pradesh conclude that socio-economic attributes such as shortage of land, population growth and disintegration of joint family system have also led to a decline in the local soil fertility management practices. Farmers of all size classes, belonging to all social groups, be it tribal or non-tribal, progressive or non-progressive, never believe that they cannot harvest to a scale as is claimed by scientists with use of fertilisers (Anonymous, undated; Reddy, 2011a). Many a time, research and extension systems appear to have a limited knowledge about investments made by farmers on organic techniques and soil conservation relative to their investments on mineral fertilisers (Reddy, 2010 b).

Plant nutrients used to replenish what is actually removed from the soil to meet the global demand of food fibers are estimated at 230 million tonnes (Vivek *et al.*, 1997). Thus, it is important to adopt a holistic approach based on the strategy of integrated nutrient management (INM) (Gruhn *et al.*, 2000). The INM strategy recognizes the importance of nutrient recycling using crop residues and other biosolids such as manure and compost; increasing biological N fixation (BNF) through leguminous cover crops; using mycorrhizal inoculation, and applying chemical fertilizers and organic amendments. In this connection, establishing a link between livestock and land is very important (Naylor *et al.*, 2005). The INM strategy is also in accord with organic farming (Macilwain, 2004). However, the INM practices being advocated in semi-arid areas are often not based on the indigenous technological knowledge possessed by farmers and do not take into account the basic needs of farm family, farm size, social groups and their perceptions (Anonymous, 2000).

There are social benefits associated with soil conservation, such as avoiding sediment and chemical damage to fish, reservoirs, roadside ditches, and other downstream water users. Walker (1982) observes that erosion-damage function reflects only the private profitability of the conservation decision. So, the social benefits may warrant conservation when the private profitability alone would not. Also, a social rate of discount that is lower than the private rate could indicate social profitability even when private profitability is absent. Wide variations in nutrient balances and economic returns observed between farms and crops demonstrate how SFM gets affected by socio-economic factors (Hilhorst and Muchena, 2000; Reddy, 2011b). This aspect needs to be taken into account while developing strategies to promote technologies for sustaining or improving soil fertility. Policy response to Integrated Soil Fertility Management (ISFM) in research and extension processes needs to be devised as a bottom up approach. In order to promote ISFM effectively, there is a need for approaches that allow for close interactions between farmers, researchers and extension workers (Scoones, 2001; Reddy, 2011a) with a special attention given to small and marginal farmers.

There is a considerable diversity observed with respect to farmers' conditions and soil fertility management strategies and the fact is that no ready solution to improving soil fertility management (Hilhorst and Muchena, 2000; Reddy, 2010b; Reddy, 2011a). Thus, it is just not enough to simply develop improved technologies. It is also important to create a more favourable context for agriculture and a good market for agricultural products, so that which inturn can act as a positive incentive for farmers to engage themselves in farm production and to make further investment on their soils.

b) Institutional Credit

Successful farming depends upon an adequate provision of agricultural finance, as it enables farmers to meet their input requirements. Its scope is wide enough to include in its purview, the supply of finance for other needs of cultivators. Any inadequacy in its supply is bound to have serious repercussions on agriculture. Findings of various studies related to credit are presented as follows.

Poor households' access to inputs is often possible only if credit institutions or savings schemes (formal and informal) that allow farmers to share and finance the purchase of external inputs (fertilisers or concentrates) are in place. A good example of a local institution that facilitates access to nutrient resources is the tradition of exchanging crop residues by sedentary farmers for manure from livestock belonging to pastoralists (Reddy, 2010a). Institutions that facilitate household access to nutrient resources are also receiving increasing attention (Williams *et al.*, 1997; Butterworth *et al.*, 2003; Reddy, 2011a). Institutional factors such as the availability of institutional credit do not affect the extent of degradation (Reddy, 2000).

High input solutions, based solely on external inputs of mineral fertilisers, are often too costly for poor farmers to afford, especially where credit markets are inadequate and distorted. Equally, an analysis of low input organic alternatives shows that harvesting, transforming and incorporating the necessary biomass are often too costly in terms of land and labour requirements to be considered by many farmers (Scoones and Toulmin, 1999; Butterworth *et al.*, 2003). This fine-tuned approach to nutrient management is knowledge-intensive and requires a range of skills. Combining small amounts of chemical fertiliser with organic fertilisers like FYM is an effective compromise for many farmers (Adolph and Butterworth, 2002; Butterworth *et al.*, 2003; Reddy, 2010a). Reddy (2011a) find that there is currently no substantial support for organic market and that formal credit is not made available to farmers for purchasing FYM or compost (unlike chemical fertilisers). Hence, credit need to be provided in a big way to dryland agriculture by finance institutions (Rao, 1991).

Sustainable management of natural resources calls for appropriate market and institutional mechanisms (Reddy, 2000). Markets for natural resources either do not exist or are distorted. Since land degradation appears to be in its early stages and is reflected mostly in input intensity and mix, information imperfections constrain farmers from adopting mitigating measures. The state should direct its efforts towards bridging the information gap through extension services. Besides, strengthening of the extension network is very much needed to overcome the problems associated with land degradation (Reddy, 2000). Institutions like Self Help Groups (SHGs) and non-banking financial companies have to play a major role in meeting the credit needs of farmers (Vyas, 2000). It is important to note here that SHGs have proved that the poor are credit-worthy even without subsidies.

A greater dependence on local money lenders, fertiliser suppliers and traders tends to increase exploitation in the form of higher interest rates, use of only the available fertilisers and credit-tied sales. Rural credit plays an important role in meeting the financial requirements of the resource-poor farmers (Adolph and Butterworth, 2002; Reddy, 2011a). However, cash scarcity is not the only primary constraint to fertiliser adoption. Also, there is no significant effect of off-farm income on land productivity (Holden *et al.*, 2001).

A review of studies clearly indicates that there is no significant credit support to dry land farming. Farmers in these regions borrow money from local moneylenders at very high interest rates, pledging whatever jewellery they have. Sometimes they borrow from traders against the produce, pledged for a tie-in after harvest sales (Reddy, 2001). Banks generally extend credit to cash crop cultivation wherein a major portion of the loan is spent on chemical fertilizers. However, a farmer cannot get a loan to buy FYM, which is, by all means, an excellent soil fertility enhancing technology having, in addition, several other benefits. As more than 60 percent of the land is under rainfed farming, there is an urgent need to support food crops and dry land agriculture by various financial institutions.

c) Policies

Issues related to soil management are at the top of the policy agenda these days. Many are of the view that something must be done about the declining soil fertility and increasing soil degradation. Donavan and Casey (1998) observe that most macro-economic policy instruments have multiple effects on the agricultural sector, and therefore on the uptake of soil fertility measures, the main determinant is profitability of the measures to farmers. The prices of fertilisers are determined by the global market, the exchange rate, policy variables such as taxes and subsidies-the determinants of fertiliser supply and demand in the domestic market, the transport costs from port or fertiliser manufacturer to the farm and market regulations (Donavan and Casey, 1998). The price determination process is clouded by the public sector involvement in fertiliser marketing. Efficiencies in fertiliser procurement, marketing, and use, can result in increased prices and decreased fertiliser demand (De Jager *et al.*, 1996).

The design of a strategy for soil fertility management need' to consider how best to combine intervention options in different places and at different levels over a period of several years (Scoones and Toulmin, 1999). Most of the small and marginal farmers often tend to purchase synthetic fertilisers, only because they are available on credit and/or use them when the government supplies them in every case of distress. In the context of the present crisis in dryland agriculture, a better policy instrument would be to make it possible for farmers to access credit easily so as to able to purchase whichever fertiliser they want: FYM, vermicompost or synthetic fertiliser (Adolph and Butterworth, 2002; Reddy, 2010b; Reddy, 2011a).

The five year plans of the Government of India have all along focussed on different aspects of agriculture. For the first time, the IX Plan initiated a programme of soil testing across the various agro-climatic regions in order to reduce the imbalance in the use of plant nutrients (Adolph and Butterworth, 2002). Keeping in view the prospects and challenges in the twelfth plan, the planning commission felt that for a better agricultural performance, along with better water management systems, and better quality seeds, it was necessary to give a greater attention to soil health with a particular focus on micro nutrients and carbon content (Ahluwalia, 2011). National project on Management of Soil health and Fertility (NPMSF) promotes the use of organic manuring; promotes soil amendments (lime / basic slag) in acidic soils and distribution of micro nutrients (GOI, 2008a). The Planning Commission feels that the state governments must act on several fronts through a package of interventions tailored to the requirements of given agro-climatic zones. Delivering only a few elements of the package will not produce optimal results. The extension system has more or less collapsed in most of the states.

Yet a strong system of extension is crucial for knowledge delivery. At present the principal source of information for the farming community happens to be input retailers who are more prone to conflicts of interests.

In order to facilitate the process of adoption of High Yielding Varieties (HYV)-which demand complementary inputs like fertilizers, irrigation and credit-subsidies came into existence (Gulati and Narayanan, 2000). Various subsidies play an important role in promoting the use of fertilizers contributing to significant increases in yields (Morris *et al.*, 2007), even though their contribution to agricultural growth and poverty reduction has declined steadily over time (Fan *et al.*, 2007). In 2008-09, India spent nearly 60 percent of total subsidies on fertilizers i.e Rs.99494.7 crore, which was more than 3.5 times the total public investment (Rs.28035 crore at current prices) in agriculture (GoI, 2012). The 2012-13 budget allocated Rs.190015 crore towards subsidizing food, fertilizers, petroleum products, credit, pulses, edible oils etc, of which the first two account for about 72 percent (Sharma, 2012). The Prime Minister's Economic Advisory Council (PMEAC) in its latest Economic Outlook 2012/13, argues for dismantling of fertilizer subsidy because agricultural input subsidies are progressively losing their relevance, becoming an unbearable fiscal burden and their role in contribution to productivity enhancement is fast disappearing (PMEAC, 2012). However, Sharma (2012) argues that public spending on subsiding fertilizers is desirable as marginal farmers use 140 Kg of fertilizer per hectare as against the large farmers who use only 68 Kg/ha. But researchers like Vyasulu and Gadgil (1992) observe that reduced fertiliser subsidy might improve soil fertility, which has been observed damaged across highly irrigated areas through excessive application and improper placement of fertilisers.

Reddy (2001) points out that the deliberate policy of the government to promote fertiliser consumption has led to an increase in the use of chemical fertiliser at an annual average rate of 4.74 percent. However, the consumption of fertilisers is not uniform across the states. Only six districts consumed more than 200 kg/ ha, whereas, 32 districts less than 10 kg/ha. Crop-wise fertiliser consumption disparity indicates that more than 80 percent of fertilisers is used for rice and wheat crops. However, If farming subsidies are withdrawn at one go, it is going to have a very severe effect on the net incomes of rice and wheat farmers in many states and consequently farming would become unprofitable, leading to a serious agrarian crisis (Sharma, 2012). The fertiliser use pattern in the country remains overly imbalanced with excessive use of nitrogen (Pasricha, 2001). The consumption ratio is particularly highly unfavourable in the states where cropping intensity and per hectare fertiliser use are high. Power supply influences fertiliser use indirectly through irrigation (Hanumappa and Rajasekhar, 1994). In addition, fertiliser price hike has affected the consumption of fertilisers by small and marginal farmers in semi-irrigated and dry villages. A study done by Raut and Sitaula (2012) with regard to Nepal suggested a three tier approach for SFM: (1) Farmers access to an efficient distribution of quality fertilizers must be ensured; (2) Extension services must be strengthened focusing on the integrated management of plant nutrients; and (3) Involvement of the private sector could develop a sense of responsibility among private traders and increase their participation in the importation and distribution of fertilizers.

Policies related to livestock development also influence soil fertility management. The policy of encouraging cross-breed stock may place small farmers and the landless at a disadvantage while taking up dairying as a source of supplementary income (Adolph and Butterworth, 2002), besides having an adverse impact on the availability of FYM. Lending institutions need to understand the critical link between cattle availability and agro-biodiversity while extending loans to farmers for the purchase of plough bullocks as well as milch animals. The Integrated Rural Development Programme's (IRDP) lending policies aimed at promoting cattle-related lending have stopped doing so, instead have initiated lending for farm machines. Considering that organic manure constitutes the most critical component of the rainfed farming system, policies to increase cattle wealth in villages should be revived (NBSAP, 2001; Reddy, 2011a). Soil fertility management options available to farmers are being undermined by government policies that focus to chemical fertiliser-based strategies (Adolph and Butterworth; Reddy, 2010b; Reddy, 2011a). Motavalli and Anders (1991) observe that the high opportunity cost of dung for use as fuel has reduced its application to crops. According to them, biomass shortage limits farmers' ability to retain stubble on croplands during the dry season, rendering the lands highly prone to erosion by early rains.

Reddy (2010a) argues that policies focused on short-term productivity gains may encourage soil degradation rather than conservation. These include fertiliser and irrigation subsidies that may discourage soil conservation and encourage depletion of groundwater. National policies need to be oriented towards improving the economics of the farming sector by ensuring better access to markets, reviewing pricing policies and regulations, promoting investment in infrastructure and reducing the risks of farming through provision of safety nets (Hilhorst and Muchena, 2000). More importantly, such a policy framework needs to be broad-based and multi-sectoral.

Soil Fertility Initiative (SFI) is one of several supranational initiatives on soil fertility management that has triggered a debate on the need to address the issue of soil degradation in Africa (Hilhorst and Muchena, 2000). In certain countries such as Burkino

Faso and Ghana, it has led to the creation of a national action plan for soils. Burkino Faso, for instance, has developed a special national policy and programme for soil fertility management, which is likely to be implemented in the near future. Hilhorst and Muchena (2000), based on a study conducted with reference to Burkino Faso point to the fact that following devaluation in 1994 and structural adjustment policies, prices have risen to such an extent that they are beyond the means of most farmers, prompting them to use a variety of organic fertilisers for improving productivity. The application of mineral fertilisers depends on their cost-benefit ratio and farmers' ability to reduce the risk of burning crops. Scoones (2001) observes that farmers across all study sites of Sub-Saharan Africa have been affected by policy changes, such as structural adjustment, devaluation and land tenure reforms, as well as exogenous events such as drought. Such changes have brought about major shifts in returns to different crops, as well as the liberalization of crop marketing. Farmers are clearly responsive to such positive changes, which implies that the government has a wide range of measures which can influence farmers' decision making.

Farmers from all farm size categories are very keen on organic practices, in particular, FYM (Adolph and Butterworth, 2002; Reddy, 2010b and 2011a). In India, the demand for organically produced food has led to the emergence of community marketing and certification efforts based on trust rather than formal controls. Such schemes could provide a price incentive required for making the use of labour-intensive low external input SFM practices (Reddy, 2010b). Policies have long focused on finding external solutions to farmers' needs (Reddy, 2011a), while in the process, encouraging dependencies on external inputs, even when they are costlier, environmentally damaging and, therefore, economically inefficient when compared with resource-conserving options. The first action that governments can take is to coordinate policies and institutions more effectively. Thus, the review brings to the fore that the government policies related to soil fertility management need to be enabling interms of creating the conditions for development based more on locally available resources, local skills and knowledge.

d) Gender

In the Indian context, the role of women in agriculture is an important issue. A review related to the role of women in agriculture reveals that women play an important role in land and water management. Woman farmers, using traditional methods, have been effective in conserving soil fertility. Over the years, rural women have developed practices for an efficient and sustainable use of resources available to them. For these reasons, it is important to build upon and enhance their skills in respect of land and water management strategies besides involving them in protecting and sustaining land and water resources (FAO, 1997). Reddy (2001) finds that women account for about 63 percent of a total of 519 person days spent by the average household on all activities including household chores. Excluding household chores, this share falls to 55 percent. According to a study conducted across the hills of Nepal (Devika, 1993), women carryout all the soil fertility management related activities except the application of chemical fertilizers. Similar has been the finding of Reddy (2010a) in respect of Andhra Pradesh.

Women play an important role in the cultivation and conservation of biodiversity across dry lands. Crop diversity is closely associated with specific soil types, which in a sense nurture it. Women's role and knowledge are being steadily marginalized and undermined by the market forces. Documentation and analysis of women's knowledge may help establish policy guidelines that may place women's practices at the center of Indian agricultural policies (Satheesh and Reddy, 2000; Reddy, 2009). Woman farmers prefer maximum crop diversity in their farms. They have an intricate understanding of their soils and make the most of the poor soils by adopting biodiverse mixed farming (Poinetti and Reddy, 2002 and Reddy, 2010b). Due to chemicalisation of agriculture the availability of uncultivated food crops (greens that grow naturally due to FYM application) for women has considerably decreased (Satheesh and Reddy, 2000; Reddy, 2011c). According to Chweya and Eyzaguirre (1999) women are the major custodians and users of genetic resources of traditional leafy green vegetables. They are also responsible for their processing, cooking and sale in the local markets.

In rainfed areas, where mechanisation has limited scope, the intensification of agriculture will necessarily and in all probability, increase the work load of female workers. The increased demand for nutrients is expected to have a positive impact on the opportunity or work and income of the farm families with female participants being an integral part of it. Hence, women should be involved in the decision making process of Integrated Nutrient Management programme (Anonymous, undated).

A majority of women play a monopolizing or dominant role in agricultural production tasks (Dak *et al.*, 1987). All the tasks related to care and maintenance of livestock is predominantly carried out by women (Sreedevi, 1996; Reddy, 1996; Reddy, 2011a). Their contribution towards agricultural output and family income is very significant, particularly in respect of small sized holdings (Patnaik and Debi, 1987; Shashikala *et al.*, 1990). Despite such significant contributions, there is evidence of labour market imperfections, especially with respect to female labour (Shiferaw *et al.*, 2003). Optimising the use of land is the logic that pervades many of the individual and collective practices of dryland farming. Thus, women are the main protagonists in farming activities, and in a sense, keepers of that logic also. Their understanding of the nature of land and its contributions to climate and crops; and their interactions, make for a type of agriculture that is well adapted to the environment and responds to as many as their needs.

IV. Ecological Dimension

a) Sustainability/Degradation.

'Sustainability' is the basis for survival of a practice/technology for years. Given the diverse nature of agro-ecological zones, the technology/practice has to fit well into it. Unless it has an inbuilt component of sustainability, the practice will not last long. Various studies have looked at the ecological costs of prevailing technologies, especially from a soil health point of view.

Soil and environmental sustainability are also essential to human health (Melnick *et al.*, 2005). There exists a relationship between the depletion of natural resources and increasing competition for limited soil and water resources and malnutrition and basic public health problems (McMichael *et al.*, 2007). High-level nutrient losses will have a direct effect not only on farm productivity but also on the life of children and infants. Based on a report of International Food Policy Research Institute, Adolph and Butterworth (2002) point out that in Sub-Saharan Africa, the proportion of children who die before the age of five is highest in the areas with a high degree of soil degradation and that a little over half of all mortalities occur in areas with a high degree of soil degradation. Soil degradation affects food insecurity directly and indirectly. Directly interms of a reduction in crop yields and a decline in their nutritional values (proteins content and micronutrients etc.) and indirectly interms of a reduction in the use efficiency of inputs (eg, fertilizer, irrigation water) and additional land required to compensate for the loss of production. The loss of household income is another indirect effect with an adverse impact on access to food. Other indirect effects of soil degradation are those related to pollution of soil, air and water with severe impacts on human health (Pimental *et al.*, 2007).

Sustainability of farming systems depends upon the physical environment, resource availability and socio-economic conditions of households (Reddy *et al.*, 2001). Reliance on data from nutrient balances provides only a snapshot at one point of time, with which the direction and evolution of the farming systems in question are hard to determine. Data on nutrient balances demonstrate a mixed pattern of accumulation and depletion, depending on plot, farmer and location (Scoones, 2001).

Soil fertility management is only one of the several important constraints faced by farmers in general. It has been found that in dry land areas, due to the adoption of various soil fertility management practices by farmers, there is little evidence that soil productivity is on the decline (Adolph and Butterworth, 2002). This is contrary to the finding that soils in rainfed areas are in a stage of declined productivity; there have been losses due to erosion and degradation (Tanner *et al.*, 2000). An analysis of the nutrient balance in Semi-arid India reveals that nutrient removal by crops is far in excess of nutrients added through fertilisers, resulting in a negative balance of 5.5 million tonnes of NPK (Katyal *et al.*, 1997). A wide range of organic inputs, which require labour intensive processing, are utilised by farmers (Selvaraju *et al.*, 1999; Reddy, 2010b and 2011a).

Farouque and Tekeya (2008), based on their study related four districts of Bangladesh, conclude that the current use of chemical fertilizers by farmers in the study areas has caused nutrient depletion in addition to lower crop yields. Maintenance of the nutrient cycle is essential by returning to soils, part of the nutrients that come from soils either directly as organic fertilisers or indirectly as manure from farm animals (Reddy, 2010c; Reddy, 2011a). However, in view of the supply of nutrients in inorganic form, a wide gap between the humus required in crop production and the humus added as manure has naturally developed. Across all size classes, farmers express concern about the negative impacts of chemicals on soils such as hardening and compaction, the soil becoming "addicted" to fertiliser applications and the scorching of crops (Reddy, 2011a and 2011b). Increased application of fertilisers may only artificially boost yields in the short run even on severely degraded soils (NBSAP, 2001; Adolph and Butterworth, 2002; Reddy, 2010a). However, physical and biological properties of soils are integral to farmers' management practices.

Chemical fertilsers are a ready source of nutrients that bring about fast results and good yields for some farmers, whereas, the poor and marginal farmers do not like to rely upon chemical fertilisers (Butterworth *et al.*, 2002; Reddy, 2011a). Fertiliser recommendations often appear unattractive to small holders, because they ignore soil and climatic variations found in smallholder farming areas, and the risks faced by such smallholders (Piha, 1993; Donavan and Casey, 1998; Reddy, 2010a). Most agronomic recommendations prove to be seriously unfit to the heterogeneous characteristics of peasant's ecology and economy (De Janny, 1981). However, plant and soil scientists often argue that farmers do not generally adopt recommendations, may be because such recommendations are not appropriate or specific enough to the local circumstances (Swarup and Gaunt, 1998; Reddy, 2011a). The access to certain subsidized inputs by upland farmers might prove to be a disincentive when it comes to controlling long-term productivity damage of soil erosion (Barbier, 1990). The land with different Indigenous Soil and Water Conservation (ISWC) measures maintains higher soil productivity than unconserved land. Long-term productivity decline and reduced returns to soil conservation are still considered major problems especially for the resource-poor farmers.

As farming becomes more intensive in rainfed areas, deficiencies and toxicities of plant nutrients often threaten a sustained crop production from the existing resource base. In rainfed lands, a somewhat careless use of some fertiliser nutrients, especially nitrogen, results in a negative effect on crop growth with associated adverse effects on environment provoking public demands for restrictions on fertiliser use (Anonymous, undated).

The Green Revolution created initially perception that soil fertility could be enhanced through chemical factories, with agricultural yields measured only through marketed commodities. Pulses and millets with high yields, from the perspective of returning organic matter to the soil, were rejected as "marginal" crops (Shiva, 1991). Biological products not sold on the market, but used as internal inputs for maintaining soil fertility, were totally ignored in the cost-benefit equations of the Green Revolution miracle. They did not appear in the list of inputs because they were not purchased; and they did not appear as outputs because they were not sold. On the other hand, some researchers view that the problem does not lie with the green revolution technology. Rather, its misuse and mismanagement has led to environmental problems. It is over fertilization, overuse of population, over simplification of crop rotation, excessive application of flood-based irrigation, unnecessary ploughing, complete removal of crop residues, and uncontrolled communal grazing which have exacerbated the soil and environmental degradation. This problem lies in using "technology without wisdom" (Lal, 2007). Crop diversity, land productivity, input use index, integrated pest management, eco-system management, soil environment level, crop productivity, enterprise supporting ability, social equity and carrying capacity are some of the important indicators of sustainability of agriculture (Nagabushanam, 1997).

Farouque and Tekeya (2008) find that 86 per cent of the respondents use different forms of organic manure at different quantity levels and only 14 per cent respondents do not use any type of organic manure for their crop production. Similarly, when it comes to the use of inorganic nutrients (chemical fertilizers) by farmers, only 13 per cent are found using the recommended dose of fertilizers as suggested by crop production specialists, while the remaining 87 percent either apply fertilizers based on their own assessment of the soil's needs or adopt part of the recommended dose of fertilizers. Depletion of Soil Organic Matter (SOM) leads to the deterioration of the soil structure, reduced soil- water and nutrient-holding capacity and reduced microbiological activity (Wommer *et al.*, 1994; Reddy, 2010b; Reddy, 2011a). Declining levels of SOM reduce the efficiency of fertilizers (Reddy, 2010a). Conventional mechanisms for adressing the loss of SOM in rainfed, low input systems include fallowing, rotations (especially involving legumes), addition of animal manure, and various forms of inter cropping and reduced tillage (Kumwenda *et al.*, 1995; Hilhorst *et al.*, 2001; Reddy, 2011b). Furthermore, Butterworth *et al.* (2003) and Reddy (2011a) observe that besides adding nutrients, FYM adds organic matter to the soil, improving soil properties in the process. Indigenous knowledge of agriculture is a valuable resource and an essential foundation for the development of sustainable agriculture (Bowensha, 1986; Amman, 2007; Kumar, 2010).

Mineral fertilisers are expensive and are not always readily available to farmers (Hilhorst and Muchena, 2000; Reddy, 2010a; Reddy, 2010c; Sharma, 2012). Hegde and Sarkar (1990) view that even the so-called balanced use of chemical fertilisers alone will not be able to sustain productivity due to the gradual emergence of deficiency of one or more secondary and micro-nutrients. More than 40 percent of the small holders who apply recommended rates of fertilisers achieve low yields and fail to cover the costs of fertiliser application (Conroy, 1993; Reddy, 2010a; 2011a).

Farmers are usually rational decision makers, in that they weigh the costs of any practice against the potential benefits that are likely to be derived, attempting to make a net gain (Butterworth *et al.*, 2003). Pretty (1998) observes that it is of central importance to realize that "few farmers are able to adopt whole packages of conservation technologies without considerable adjustment of their own practices and livelihood systems. Hence research should aim to support the use of organic inputs as the source for most of the necessary nutrients, making up the shortfall with mineral fertilizers".

Healing and recovery of soils will not emerge by continuing to cling to the market as an organizing principle for agriculture. Recovery of dying soils lies in rediscovering natural ways of renewal and learning; once again, to see that the soil has the right to a share of its produce in order to renew itself. Respecting that right is critical to satisfy our needs (Claude *et al.,* 1999; Reddy, 2010a). The Green Revolution paradigm substitutes the nutrient cycle with linear flows of purchase inputs of chemical fertilisers from factories, while focusing on the production of marketable agricultural commodities (Shiva, 1992).

The reasons for the disappearance or gradual decline of strong traditional SFM practices, include state policies which have encouraged chemical fertilisers; the diminishing cattle wealth in the villages; mechanisation of farm operations; tenancy issues; state-gifted unproductive lands where high investments are needed that cannot be afforded by farmers; and desperation for continuous production and hence, the impossibility of resting the land for a season or two (Adolph and Butterworth, 2002; Reddy, 2010a; Reddy, 2011a). Land productivity, in terms of value, has been found significantly lower (30-40 percent) for non-cereal crops than for cereals (Holden *et al.*, 2001). The fact that households still prefer to grow these crops may be not only due to market imperfections causing a subsistence orientation of production, but also may partly be explained by positive crop rotational benefits on land productivity that is not captured in a short run analysis.

The practice of inter cropping provides for the stability of production over seasons besides ensuring of additional employment to the farm family and a great solar energy harvest. The advantage of inter cropping is realized due to the temporal and spatial complementarity exhibited by the crops grown in association. Inter cropping safeguards against total crop failures under unfavorable climatic conditions and can increase production and income from drylands (Reddy, 2010b; Reddy, 2011a). Adopting Conservation agriculture is another soil management approach proven useful in sustaining soil quality (Lal, 2009). Converting to conservation agriculture comprises: (a) adopting no-till (NT) farming with minimal or no soil disturbance; (b) maintaining crop residue mulch on the soil surface; (c) adopting complex/diverse crop rotations; (d) following INM strategy to enhance soil fertility; and (e) using integrated pest management (IPM) techniques to eradicate weeds and control pests and pathogens.

Integrated Nutrient Management (INM), which essentially combines organic and mineral methods of soil fertilization, has come to be widely accepted in both international and Indian scientific circles as the most appropriate soil fertility management strategy for rainfed farmers (Scoones *et al.*, 1998). As evidenced in many studies (Chambers, 1991; Pretty and Shah, 1997), participatory methods are the key to successes or failure of INM approaches.

Under farm conditions, the recommended fertiliser application rates are simply unprofitable. Unless the basket of combinations is widened with more environment-friendly and profit- oriented combinations there is a possibility of unviability. Return to technology must be viewed not only from an economic analysis point but also its contribution to sustaining soil quality and life (Reddy, 2011a). A greater demand for organic inputs is expanding the market for organic fertilizers (Reddy, 2010b). Appropriate economic incentives can encourage farmers to use more and more of organic fertilizers (Reddy, 2010a).

There is no direct link between poverty and environmental degradation (Reddy, 2001). Removal of poverty is not a necessary condition to attain sustainable development though poverty alleviation by itself is an important policy objective. Interestingly, salinity is positively associated with the availability of tractors and negatively with draught power. And rainfall does not have any influence on soil degradation, indicating that degradation is not a natural phenomenon (Reddy, 2000). Intensive cultivation practices such as higher cropping intensities and irrigation associated with excess input use would result in degradation (Reddy, 2000). The possible impacts of these factors could be mixed, whereas, the availability of livestock is associated with less irrigated regions. Use of livestock for agricultural practices is less degrading as compared to tractor use. Moreover, the availability of livestock can provide the much-needed farm yard manure for complementing the chemical fertilisers. Livestock is said to have a negative impact on degradation, but at the same time the composition of livestock can also influence the extent of degradation (Reddy, 2000). It is often argued that small ruminants such as sheep and goats degrade land more as compared to large ruminants. The adverse effects of soil degradation on human health and well being can be overcome through soil restoration strategies based on management of drought stress, soil infertility and deficiency of micro elements (Lal, 2009).

The most important determinants of farmers' investment decisions are related to soil quality variables, access to credit, labour force, scarcity of land, off-farm income, and social capital (Shiferaw *et al.*, 2003). Soil quality variables seem to have a positive impact on conservation investment decisions, indicating that farmers are more interested in maintaining current fertility levels than reclaiming the degraded plots. However, the likelihood of investing on soils perceived to have low a risk of degradation (like the vertisols) is low. Controlling for quality of land and scarcity of land as reflected in low land-person ratios encourage conservation related decisions (Reddy, 2000). As off-farm income increases as a means of livelihood, the incentive to invest in sustainability seems to decline significantly.

The subject of ecology of soils has been largely neglected even by scientists, not to mention farmers. Carson (1962) emphasises that our main concern should be about the incredibly numerous and vitally necessary inhabitants of the soil when poisonous chemicals are carried down into their world, either introduced directly as soil "sterilants" or borne on the rain that has picked up a lethal contamination as it filters through the leaf canopy of forests, orchards and croplands. Sustainable agriculture can be referred to as regenerative agriculture a way of accepting the principle of co-existence of soil microbes, livestock and the tree component, which leads to natural farming for future prosperity (Vijaya, 1996). According to Bollaki and Badanur (1997), *in-situ* incorporation of sunhemp reduces the bulk density as compared to fertiliser application while the application of fertilisers with sunhemp improves the infiltration rate, water table aggregates, porosity, field capacity and maximum water holding capacity under dry-lands. Mechanisms such as conservation tillage, slowing down land conversion, reducing erosion, or management of organic residues can all contribute to the reduction of GHG emissions, while promoting soil health and there by supporting the local communities (Lal, 2004).

An economic analysis shows that if returns to manure use were calculated simply based on its contribution to soil nutrient status, it would not be profitable. However, there is also value to SOM's contribution to sustaining the soil's physical characteristics. Hilhorst and Muchena (2000) find that the least amount of SOM loss under cropping results from the use of manure plus fertilisers (24 percent) as compared to the no treatment case (46 percent) or just the use of fertilisers (45 percent). Application of organic manure to the soil can improve the hydrophysical environment, fertility of the soil besides sustaining crop productivity levels (Wani *et al.*, 1994; Sharma, 1991; Maskina *et al.*, 1998; Reddy, 2010a and 2011a). As for black soils, the cumulative effect of addition of organic matter in soil over seven years indicates that the physical properties of soil, especially the structural stability improves considerably because of the cementing effect of humic substances of organic matter with soil particles (Patil *et al.*, 1996). The cycle of erosion normally starts when you stop putting organic matter to the soil (Claude *et al.*, 1999; Reddy, 2010a).

The constraints in the adoption of dry land technology are high cost of inputs, shortage of capital, lack of knowledge of improved practices, fear of loss due to failure of rains, non-availability of inputs at appropriate time, etc. (Reddy *et al.*, 1986). Land degradation is critically linked to sustainable development, especially in agrarian economies like India (Reddy, 2000). As far as land degradation is concerned, the population pressure does not seem to exert any pressure. Poor people living in the fragile resource regions are the prime victims of land degradation process irrespective of the fact that they do not contribute to the process. The problem of soil degradation must be tackled on community basis with incentives designed to encourage individual participation in collective works (Hilhorst and Muchena, 2000). The underlying principle is to take whatever steps possible to "internalize" economic externalities.

Suggestions given by farmers to overcome the constraints involved in the adoption of sustainable farming include research on ecological farming practices, making available biofertilisers and neem products at subsidized rates by the government, establishment of bio-gas plants for getting organic manure, strengthening of the extension system for immediate dissemination of proven sustainable farming, providing quality seeds and training to farmers on proven sustainable farming, timely availability of inputs and more diversification in agriculture (Kappala, 2002; Reddy, 2010a and 2011a).

Based on the review, we can say that agricultural research should aim at supporting organic inputs as the source for supply of nutrients. This will help strengthen sustainable soil fertility management practices. Agricultural scientists, administrators and policy makers need to change their attitude and accept the traditional subsistence agro-ecosystems as the product of ecological rationale instead of viewing them as being primitive. Phasing and tailoring of soil fertility interventions will require a multifaceted approach which broadens the debate away from a purely technical focus as sustainable management of natural resources calls for appropriate market and institutional mechanisms.

b) Management

Various cropping systems (agroforestry, silvipastural systems, ley -farming, etc.), animal crop residues, bio-fertilisers, etc., help enhance the biological productivity of the soil systems. These provide balanced nutrition by enhancing the natural biological soil processes and protecting the soil from further degradation. Reddy (2011) suggests the adoption of farming practices using crop rotation. Acharya *et al.* (2001) indicate that the deleterious effects of allelochemicals such as suppressive effects on germination/ establishment of crops is more pronounced under monoculture due to accumulation in soil, while the effect is very low under crop rotation. Even weed species help enrich nutrients in soil and, hence, are useful as soil amendments (Acharya *et al.*, 2001 and Reddy, 2011c).

Fertiliser use has been commonly initiated with the advent of high yielding crops that help to make profits. The recommended application rates are mostly based on nation-wide blanket fertiliser recommendations, regardless of location. The farmers have responded to shortages of manures and declining soil fertility by using mineral fertilisers and manure more intensively, focusing their use in niches which offer better returns or which are perceived to be infertile (Hilhorst and Muchena, 2000; Reddy, 2010a). There has been a shift away from mineral fertilisers towards the use of organic inputs. Although there is little difference observed in the range of organic amendments used by individual households, there are considerable variations in the quantities used (Reddy 2010b). Recommendations made by research and their extensions have failed to recognize these changes in farming practices, which should be informative to research agenda. Researchers need to emphasize the use of a diverse regime of fertility inputs and the designing of more flexible fertility recommendations that reflect variations in soil types as well as the capability of crops to reward farmers economically (Reddy, 2011a).

There are two main approaches to improved soil fertility management. One is to attempt to meet the plant requirements with purchased mineral fertilisers. The second relies on biological processes to optimize nutrient cycling, with a minimal emphasis on external chemical fertilizers, but maximising the efficiency of their use. Integrated Nutrient Management (INM), a more sustainable middle path that combines the best features of both the approaches is better than either alone (Sanchez, 1995; Scoones and Toulmin, 1999a; Green land *et al.*, 1994; Thakur, 1991; Singh *et al.*, 1998). While more fertilisers are being used effectively, for attaining sustainable agricultural growth in Africa, technologies that use organic resources are equally essential and in some cases, more appropriate and feasible, given the complex, resource-poor farming systems (De Jager *et al.*, 1996; Reddy, 2011a).

Land is becoming an increasingly scarce resource and farmers have to contend with degrading soils and declining levels of fertility. Nutrient balances are more negative for outfields which are subject to erosion and leaching (Hilhorst and Muchena, 2000). Farmers find it difficult to produce and transport enough good-quality organic fertilisers to their fields, and many of them cannot afford to buy sufficient mineral fertilisers to complement organic inputs. Not enough organic fertiliser is being produced and applied to bring the partial nutrient balances into an equilibrium (Hilhorst and Muchena, 2000; Reddy, 2010a; Reddy, 2011a). Without appropriate economic incentives upland farmers will not modify their land management practices and farming systems (Barbier, 1990). Under farm conditions, fertiliser application rates may be simply unprofitable (Hilhorst and Muchena, 2000; Reddy, 2011a). Some-times, fertiliser costs are likely to subject the farmer to a greater financial risk than the purchase of improved seed (Kumwenda *et al.*, 1995; Reddy, 2011a).

As far as private resources are concerned, access to resources and markets play a predominant role in household decisions (Reddy, 2001). Although households are concerned with environmental and sustainability aspects, it is economic rationale (output optimisation and profit maximisation) that receives a higher priority. This indicates that concern for inter-generational equity are more or less absent. Market forces have become dominant with the commercialisation of agriculture. Households pick up from the available basket of combinations (crop and input technologies) that would give them maximum utility (profit). Unless this basket of combinations (technologies) expands with environment-friendly and profit-oriented combinations, the present trends are likely to continue (Reddy, 2010a and Reddy, 2011a).

Although the constraints involved in the adoption of technologies are reasonably well understood and appreciated, the programmes for improving adoption are not clear and do not address the central problems of non-adoption such as farmer participation in research formulation and execution on farmers' fields (Adolph and Butterworth, 2002). For "successful" soil fertility research, emphasis of the project should not only be on solving soil nutrient constraints with improved mineral fertilisers but also should incorporate on-farm research and extension activities (Kumwenda *et al.*, 1995; Reddy, 2010a). There should be participatory planning, analysis and facilitation of farmer-led experimentation, by way of supporting processes of learning and exchange, and major changes in the roles of research and extension staff (Scoones and Toulmin, 1999b; Reddy, 2011a). In addition to the participatory development and adaptation of technologies that are appropriate to the constraints and opportunities faced by farmers, researchers will have to direct more energy towards building partnerships, establishing joint experimentations and presenting the insights gained from research to a wider audience.

In view of the increasing demand for food production and improvements in its nutritional quality, there is a need for change in the context of agricultural science (Evans, 2005; Brklacich *et al.*, 1991). It is equally important to understand how sustainable agriculture can address both the environmental concerns and human health issues (Horrigan *et al.*, 2002), diffuse and minimize pollution from agricultural practices (Burkart, 2007), predict changes in crop productivity over time (Ewert *et al.*, 2005) and adapt to ecological systems (Giloli and Baumgartner, 2007) in the context of changing social needs.

V. Conclusion

Sustainable soil fertility management is the key to food and livelihood security of millions of people living in semi-arid regions. Although chemical fertilisers are a ready source of nutrients that bring about fast results and good yields for some farmers, the poor and marginal farmers are much reliant upon SFM practices that are based on local resources and knowledge. Unfortunately, most agricultural researchers and extension agencies focus their activities on chemical fertilisers, which do not facilitate livelihood opportunities. Livestock are crucial for maintaining soil fertility, supply of draught power, food for the family and increasing the agricultural productivity of dry lands. Hence, a better integration of crop and livestock system is essential (Naylor *et al.*, 2005).

INM practices, which are being advocated in semi-arid areas are often not based on the indigenous technological knowledge of farmers not do they take into account the basic needs of farm family, farm size, social groups and their perceptions. Soil fertility management options available to farmers are being undermined by government policies that give more importance to chemical fertiliser-based strategies. This literature review reveals that policies have long focused on finding external solutions to farmers' needs, despite the fact that farmers from all farm size categories are very keen on using organic practices, in particular, FYM. In order to promote Integrated Soil Fertility Management (ISFM) effectively, there is a need for approaches that allow for close interactions between farmers, researchers and extension workers (Scoones, 2001 and Reddy, 2011a). A special attention should be given to small and marginal farmers. The basket of soil fertility management combinations (technologies) need to be expanded with environment-friendly and profit-oriented strategies.

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