



Integrated farming systems for prosperity of marginal farmers and sustainable agriculture: a roadmap for India

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ABSTRACT

Agriculture in India and other Asian countries is facing multiple and complex challenges which are expected to become severe with the passage of time. Some major challenges are sustainability of natural resources, impact of climate change and decline in factor productivity. Besides, declining trend in size of land holding poses a serious challenge to the profitability and sustainability of farming. In view of the decline in per capita availability of land, it is imperative to develop strategies and agricultural technologies that enable adequate employment and income generation, especially for smallholders (farmers with < 2.0 ha land) who constitute the vast majority of the farming community in the developing world. No single farm enterprise, such as a typical monocropping system, is likely to be able to sustain the smallholder farmer. Integrated farming systems (IFS) are less risky if managed efficiently, as they benefit from synergisms among enterprises, diversity in produce, and environmental soundness. On this basis, IFS have been suggested for the development of small and marginal farms across Asia, and researchers have developed strategies which have benefitted smallholder farmers by providing additional income and employment and minimizing risk. However, these IFS have not been promulgated and promoted effectively. The present review helps solve this by providing comprehensive information on innovative concepts, approaches and strategies for promotion of IFS for small-holder farmers, which is lacking at present.

Key words: Integrated farming systems, Small and marginal farmers, Sustainability, Roadmap

Agriculture in South Asia is at cross-roads in terms of achieving sustainability mainly for three reasons, the region is finding it difficult to generate adequate income and employment for its vast farming population, failing to achieve environmental and energy security at the farm level, and failing to cope with climate change (Behera and France 2016). Faced with this situation, such agricultural strategies need to be explored that increase productivity and generate adequate income and employment for the small-holder farmers, as well as generate renewable energy on the farm, and stop the erosion of biodiversity and offset carbon emissions (Behera *et al.* 2015). The economic limitation of small-sized land operations is the main challenge to sustainable farming in the 21st century. This calls for structural and organizational changes in managing the farm sector in South Asia (Behera and France 2016). The important issue is how to develop institutional mechanisms so that farmers get higher incomes by realizing the advantages of beneficial technologies, aggregation of inputs and outputs, and value addition and marketing.

The remarkable growth of Indian agriculture over the last five and half decades, i.e. after the advent of Green Revolution (i.e. cereal production) technologies, has ushered

in an era of self-reliance in food grain production, improved rural prosperity and has brought in an element of resilience into agriculture (Evenson and Gollin 2003). Food-grain production, which was 50.8 million tonne (mt) in 1950–51, was raised to 196.8 mt by 1997. The impact of the Green Revolution was so impressive that India became a role model for many developing countries. Concerted efforts made by researchers, farmers and policy makers transformed India from begging-bowl to bread-basket status within a short period of a decade or so. Obviously, this proved a matter of national pride and great satisfaction to the scientists and farmers of the country.

In the backdrop of past glory, unabated growth of the Indian population and its large scale (60%) dependence on agriculture, continue to pose a serious challenge for planners and agricultural scientists alike (Falcon *et al.* 2005). Assuming present trends, the Indian population is estimated at 1.3 billion by 2020, sharing resources with a very large livestock population. On the basis of present consumption patterns, estimated total requirement for foodgrain will be around 300 and 350 mt by 2020 and 2030, respectively, as against present production of approximately 270 mt. For these two years, the demand for edible oil, milk, vegetables and fruits is expected to rise to 7.9 and 9.5, 93.1 and 119.5, 93.6 and 110.7, and 53.7 and 70.5 mt. Similarly, a 30–50% increase in demand is anticipated for marine and livestock

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products from present levels of 5.4 and 3.6 mt, respectively.

In other words, to keep pace with the food requirements of such a large population, there is an urgent need to accelerate all aspects of agricultural food production with due consideration to restoration and conservation of natural resources, which can only be achieved through sustainable resource management and the adoption of farmer-participatory holistic approaches (termed the farming systems approach). The farming systems approach is considered a resource management strategy to achieve economic and sustained productivity that meets the diverse requirements of the farm household whilst preserving the resource base and maintaining a high level of environmental quality (Lal and Miller 1990). Farming systems research is considered a powerful tool for natural and human resource management in developing countries including India. This multidisciplinary whole-farm approach is very effective in solving the problems of small and marginal farmers (Behera 2010, Mahapatra and Behera 2011). The approach aims at increasing income and employment from small-holdings by integrating various farm enterprises and recycling crop residues and by-products within the farm itself (Ahlawat *et al.* 2002, Rautaray *et al.* 2005).

The structure of Indian agriculture is undergoing transformation. A notable feature of changing farm structure is the dominance of smallholders whose number has increased over time and will continue to do so in future (Table 1). The traditional monoculture and disciplinary approach is unable to meet the growing and changing food demand and improve the livelihood of these smallholders on a sustainable basis (Mahapatra and Behera 2011). Therefore, an integrated approach to farming is critical to sustain agricultural production, maintain farm incomes, safeguard the environment and respond to consumer concern about food quality issues (Singh *et al.* 1998, Yadav and Prasad 1998). However, the potential contribution of IFS to the development of a more sustainable agriculture has largely

been ignored (Paroda 2014). Moreover, decline in per capita availability of land from 0.5 ha in 1950–51 to 0.15 ha in 2009 and a projected further drop to less than 0.1 ha by 2020 (Mahapatra and Behera 2011) point to the urgent need of developing strategies and agricultural technologies that enable adequate employment and income generation, with small and marginal farmers at the fore front. The problems encountered by these 2 groups of farmers are different than those having large holdings. These farms need multi-enterprise farming activities that are complementary and technically compromising in the interest of the productivity of the whole farming system. The crop and cropping system based perspective of research needs to make way for farming systems based research particularly with regard to small farmers (Jha 2003). In IFS research, integration of land-based enterprises, such as aquaculture, poultry, duckery, apiary, field- and horticultural- crops within the biophysical and socio-economic environment of the farmers is important to make farming more profitable and dependable (Behera *et al.* 2004, Rautaray *et al.* 2005). Adoption of an individual farm enterprise in isolation cannot sustain the farm family, but the IFS approach holds the promise of addressing the issues of sustainable economic growth of Indian farming communities. Integrated farming systems benefit from synergisms among different enterprises, diversity of produce, and environmental soundness (Behera *et al.* 2010). For this reason, the IFS model has been suggested by several workers for developing small and marginal farms across the country (Rangaswamy *et al.* 1996, Behera and Mahapatra 1999, Singh *et al.* 2006).

Approach to research: Holism and reductionism

The four revolutions in the agriculture sector, viz. the Green (cereal production), White (milk), Yellow (oilseed) and Blue (fish) made India self-reliant in various agricultural commodities and also made it possible to export large quantities of some agricultural produce (Borthakur and

Table 1 Number and area of operational holdings by size group (2010-11)

Category of holding	Number of holdings			Area			Average size of holdings		
	2000-01*	2005-06*	2010-11*	2000-01*	2005-06*	2010-11*	2000-01*	2005-06*	2010-11*
Marginal (less than 1 ha)	75408 (62.9)	83694 (64.8)	92826 (67.1)	29814 (18.7)	32026 (20.2)	35908 (22.5)	0.40	0.38	0.39
Small (1-2 ha)	22695 (18.9)	23930 (18.5)	24779 (17.9)	32139 (20.2)	33101 (20.9)	35244 (22.1)	1.42	1.38	1.42
Semi-medium (2-4 ha)	14021 (11.7)	14127 (10.9)	13896 (10.0)	38193 (24.0)	37898 (23.9)	37705 (23.6)	2.72	2.68	2.71
Medium (4-10 ha)	6577 (5.5)	6375 (4.9)	5875 (4.2)	38217 (24.0)	36583 (23.1)	33828 (21.2)	5.81	5.74	5.76
Large (10 ha and above)	1230 (1.0)	1096 (0.8)	973 (0.7)	21072 (13.2)	18715 (11.8)	16907 (10.6)	17.12	17.08	17.38
All holdings	119931 (100.0)	129222 (100.0)	138348 (100.0)	159436 (100.0)	158323 (100.0)	159592 (100.0)	1.33	1.23	1.15

No. of holdings: ('000), Area operated: ('000 hectares), Average size: (hectares). The figures in parenthesis represent % of the total. Source: ASG, 2015.

Singh 2013). With commodity-based research underpinning these revolutions, the main emphasis has been on the evolution of high yielding varieties and increased use of fertilizers and other chemicals combined with greater use of irrigation water, with the research mostly being conducted in isolation and at the institute level (Jha 2003, Behera *et al.* 2008, Jain 2008). This commodity-based research has proven largely inadequate in addressing the multifarious problems of small farmers (Rhoades and Booth 1982, Gangwar 1993, Jha 2003). Also, several ills have appeared in Indian farming, such as decreasing factor productivity and resource-use efficiency, and declining farm profitability and productivity (Chopra 1993, Sharma and Behera 2004, Singh 2015).

The systems view is a useful conceptual device for all concerned with agriculture as it helps researchers understand the context of their research and define its content, thus contributing to its relevance. It helps them see their specialization in perspective and in relation to other forces and creates a better climate for cross disciplinary work. It has been demonstrated that research programmes based on the traditional approach (i.e. commodity based) are not wholly sustainable, equitable and stable over a long period (Singh *et al.* 1998, Yadav and Prasad 1998). No doubt, such a research has made India self-sufficient in agricultural production; however, many associated problems have emerged in intensive farming areas which will adversely affect the nation's agricultural production (Jain 2008). Certain problems, such as recurrent pest and disease outbreaks, soil erosion, declining soil quality, pollution and increasing inequality, can be more or less directly attributed to the 'Green Revolution' itself; while others such as desertification, salinization and widespread malnutrition and famine have persisted because the revolutions so far have offered few solutions. The issue of planning research programmes, therefore, by diverting attention towards holistic conditions on the farm is being realized, and research programmes are being formulated on the basis of the farming system as a whole.

Integrated Farming Systems

An IFS may be defined as linking together two or more normally separate components or enterprises which then become subsystems of a whole farming system. Two major features of an IFS are: (i) waste or by-product utilization in which the wastes or by-products of one sub-system become an input to a second sub-system; and (ii) improved space utilization in which the two sub-systems essentially occupy part or all of the space required for an individual sub-system. Integrated farming has also been defined as the biologically IFS which: (i) integrates natural resources and regulation mechanisms into farming activities to achieve maximum replacement of off-farm inputs; (ii) secures sustainable production of high quality food and other products through ecologically preferable technologies; (iii) sustains farm income; (iv) eliminates or reduces sources of present environment pollution generated by agriculture; and (v)

sustains the multiple function of agriculture (IOBC 1983).

Thus an IFS represents multiple crops (e.g. cereals, legumes, tree crops, vegetables) and multiple enterprises (e.g. livestock, apiary, aquaculture) on a single farm in an integrated manner (Behera *et al.* 2015a). The IFS approach is holistic, multi-disciplinary, problem solving, location specific and farmer oriented (Singh *et al.* 1998). The basic aim of IFS is to derive a set of resource development and utilization practices, which leads to a substantial and sustained increase in agricultural production (Kumar and Jain 2005). However, there exists a web of interactions among the components within farming systems and it becomes difficult to deal with such inter-linking complex systems. This is a likely reason for the slow and limited progress achieved in the field of farming systems research in Asian countries.

For the small and marginal farmers of India, IFS can play a vital role in enhancing their economic situation and livelihood (Devendra and Thomas 2002a,b, Singh *et al.* 2006). Unlike specialized farming systems, IFS activity is focused around selected, interdependent, interrelated and often interlinking production systems based on several crops, animals and related subsidiary professions. An IFS involves the utilization of primary and secondary produce of one system as basic inputs to the other systems, thus making them mutually integrated as one whole unit. There is need for effective linkage and complementarities of various components to develop effective holistic farming systems (Singh *et al.* 2007).

Benefits of IFS

The advantages of IFS include pooling and sharing of resources/inputs, efficient use of family labour, conservation, preservation and utilization of farm biomass including non-conventional feed and fodder resources, effective use of manure/animal waste, regulation of soil fertility and health, income and employment generation for many people and increase economic resources. It improves space utilization and provides diversified products. IFS is a strategy to ensure sustainable use of the natural resources for the benefit of present and future generations. The important benefits from implementing IFS in a region/country are listed below.

Productivity: IFS provides an opportunity to increase economic yield per unit area per unit time by virtue of intensification of crop and allied enterprises (Manjunath and Itnal 2003a, Ravisankar *et al.* 2007, Rathore and Bhatt 2008).

Profitability: Improves profitability by reducing production costs through recycling wastes and by-products of one enterprise as inputs to other enterprises (Maheswarappa *et al.* 1998, Manjunath and Itnal 2003b, Ravisankar *et al.* 2010).

Sustainability: IFS helps in optimal and effective utilization of wastes and by-products of linked components. It gives emphasis for achieving agro-ecological equilibrium through reduced build-up of pests and diseases (Korkanthimath and Manjunath 2009, Gill *et al.* 2010, Kumar *et al.* 2011).

Balanced food: Components of a varied nature are

linked to produce different varieties of products and produce, which serve to provide a balanced diet for the farm family (Kumar *et al.* 2011, 2012, 2013).

Environmental safety: In an IFS, waste materials are effectively recycled by linking appropriate enterprises and components, thus minimizing environment pollution. It is recognized that single enterprise based farming endangers ecological security. For example, burning rice residues is common practice in intensively rice-wheat cropped areas of India (e.g. the Punjab, Haryana, Western Uttar Pradesh), resulting in vast nutrient loss and increasing the concentration of GHG in the atmosphere (Kumar *et al.* 2013). Such situations could be avoided by agricultural diversification with the introduction of more enterprises (e.g. animal husbandry) on the farm. Rice straw can be used as animal feed and turned into manure for sustaining soil health. Also, as an IFS takes into account effective resource use and nutrient recycling and makes farming less dependent on external inputs, it helps minimize environmental pollution occurring due to heavy use of external inputs (Shukla *et al.* 2002).

Resource recycling: Effective recycling of waste materials and by-products (crop residues and livestock wastes) is practiced in an IFS. Therefore, there is less reliance on outside inputs (e.g. fertilizers, agrochemicals, feeds, energy). This leads to a more stable production system (Kumar *et al.* 2013).

Year-round income : IFS provides a flow of money for the farmers throughout the year by way of the sale of a variety of farm produce (e.g. milk, egg, mushroom, vegetables, fruits, food grains) (Behera and Mahapatra 1999, Maheswarappa *et al.* 2001, Kumar *et al.* 2013).

Risk minimization: IFS provides a stable and sustainable production system through diversified crops and enterprises, which helps in risk minimization and resilience to climate change (Ayyappan and Arunachalam 2014). Single commodity based agriculture is always endangered by natural hazards such as floods, drought, and disease epidemics. During 1999-2000 in India, many cotton growers in Andhra Pradesh, Maharashtra and Karnataka committed suicide as their crops were heavily damaged by pests. Adoption of IFS would help farmers escape such situations and reduce the risk involved in crop failure (Shukla *et al.* 2002).

IFS for enhancing sustainable agriculture

Monoculture and continuous cropping or rice-wheat and rice-rice systems has resulted in various disadvantages, e.g. degradation of natural resources, build-up of diseases and pests, and decline in factor of productivity (Ayyappan and Arunachalam 2014, Singh 2015). All these have endangered the basic fabric of sustainability in some of the most productive zones of India. Crop-animal systems in Asian agriculture display a wide diversity in cropping patterns, livestock species and use of the resource base. There is evidence of positive and economic benefits from crop-animal interactions that promote sustainable agriculture

and environmental protection (Devendra 2002a). Under the stress of intensive agriculture, environmental degradation has been reported in many economically developed countries from excessive use of high energy inputs, such as fertilizers and pesticides. Use and recycling of locally available inputs and integrating them with the minimum needed quantities of external inputs would enhance the sustainability of the farming process. Use of locally available inputs, besides being environmentally friendly can keep production costs within the affordable reach of the peasants. Indigenous technological knowledge has a substantial stake in this process. IFS are useful owing to increased diversification, intensification, improved natural resource efficiency and increased productivity, as well as increased sustainability (Lightfoot *et al.* 1993, Devendra 1997, Dalsgaard and Prein 1999).

IFS for enhancing biodiversity and ecosystem services

There has been an ever increasing dominance of economically-driven highly intensive farming systems over ecologically-oriented traditional agricultural systems all over the globe. (Ehrlich and Pingle 2008). Such a shift is rapidly reducing the diversity of cropping systems and diminishing the quality of available habitats for various organisms associated with agricultural landscapes, and hence adversely affecting the existing biodiversity (Reidsma *et al.* 2006). The Indian scenario provides an excellent example. Market-oriented intensive agricultural production systems are replacing ecologically-oriented extensive traditional farming systems, and hence leading to rapid changes in the agricultural landscape. It is widely accepted that the major practices of the intensive systems that adversely affect farm level biodiversity are application of synthetic fertilizers and pesticides, cultivation of but a few high yielding varieties, continued mechanization of agriculture and the removal of semi-natural habitats in farm areas (Bianchi *et al.* 2013, Amjath-Babu and Kaechele 2015). Dhyanani *et al.* (2009) argue that conservation and sustainable use of biodiversity contributes significantly to sustainable development and mitigation, and adaptation to climate change.

IFS promotes a rich culture of biodiversity through maintaining a multi-enterprise system of flora and fauna. Behera *et al.* (2007) reported 21 species of cropped plants in an IFS under eastern Indian conditions, comprising root crops, leafy vegetables and greens, flowers, fruits seeds and nuts, agroforestry plants, trees, and medicinal plants besides the field crops such as rice, wheat, and green gram grown for grain purpose and mustard and toria for oilseeds. Such a mosaic of plant and crop species contributes for a better quality of life for the farmers by providing various items of food, fodder and fuel for the family (Behera *et al.* 2018). Rearing of cows, goats, etc. along with fish in farm ponds helps balance the diet of the family. Such multi-enterprise farming plays a vital role in making the farming system sustainable through different cropping, biodiversity and ecosystem services. Intensification of farming has a clear impact on biodiversity (Amjath-Babu and Kaechele

2015). The process of intensification includes the combined effects of ploughing frequency, fertilizer and pesticides applications, and specialization of production. Zechaister and Moser (2001), Gaston (2000) and Wilson *et al.* (2003) all demonstrated a strong correlation between land use intensity in farming and biodiversity loss.

The traditional farming systems of India are relatively stable and in equilibrium. The species complexes in traditional systems exemplify the co-existence of plants, humans, draught animals, birds, beneficial insects, pollinators, earthworms, soil micro-organisms and bio-control agents. Agricultural biodiversity and associated traditional knowledge are essential to the climate change resilience of these landscapes but their roles are largely overlooked by researchers and policymakers (Mijatovic *et al.* 2013). Modern farming systems, which evolved in response to the growing needs of society to ensure food and nutritional security, have progressively replaced traditional farming. More intensification of crops and cropping systems in modern farming has led to a decline in the genetic pool and an erosion of biodiversity, and the links among the components and enterprises are broken causing unsustainability (Dent 1990). It is important that diversity is assured while attaining high production levels and profitability. Humans, particularly women, have a long tradition of preserving plant species and the agro-ecosystem. There is a need to preserve traditional practices and learn from available local wisdom.

The genetic future of livestock populations is closely linked to crop integration in mixed farming systems (de Haan *et al.* 1997). IFS are the reservoir for many valuable indigenous breeds of ruminants and non-ruminants that have been incompletely characterized and inadequately exploited in Asia (Devendra 2002b). The intensification and industrialization of livestock production has led increasingly to the demand for uniform genotypes causing the extinction of some, and genetic erosion of other breeds. In South Asia, the crossbreeding of local breeds with a few introduced dairy breeds is proceeding on a very large scale, to the detriment of the indigenous stock. A more detailed account of the problems associated with crossbreeding is given by Devendra *et al.* (2000).

Integrated farming systems: the road map

The systems and interdisciplinary approach: A significant weakness in the research and development process and programmes in most national systems concerned with crop and livestock production in Asia is the near absence of the systems approach. Much of the research continues along strong disciplinary lines without reference to the needs of small farms (Devendra 2007). Despite the dominant emphasis on mixed farming in Asia, research on crop-animal systems is seldom integrated. As a result, the complex and interrelated system-based problems in crop-animal systems are not addressed in holistic terms. The systems approach requires multi-interdisciplinary interpretation of different components of the systems and

the biophysical environment, identified through detailed analyses of the constraints, needs and opportunities. System perspectives are, therefore, of great importance in improving, understanding and developing the contribution for the farmers.

Targeting research and development in rainfed areas:

The rationale and justification for targeting the rainfed areas of Asia are related to three important reasons: inadequate availability of arable lands, the need to increase productivity from animals to match projected human needs and the alleviation of poverty (Devendra 2000). The rainfed areas have been constrained by many factors, such as road and market access and hence, have been relatively underutilized and also bypassed by research and development. Water is another constraint, and without adequate irrigation systems, rainfed areas have been unable to increase productivity and capacity. However, these constraints can be overcome by increased research and development attention, technology delivery and market-oriented production systems. The strategy for the development of small farms must therefore give priority to rainfed areas, especially to the potentially more important locations.

Markets and marketing: Small farmers have major problems coping with a range of issues in the face of the complexity and general inefficiency of prevailing marketing chains. At present, inadequate access to market outlets and weak marketing arrangements represent major constraints in the production to consumption cycle. Market chains involve rural, peri-urban, urban and international markets, and the major challenge lies in ways to link small farmers with these markets and marketing systems. In order to provide good links between rural and urban markets, appropriate infrastructure and communication facilities must be in place, in addition to centres for collection and processing.

Extension strategy for 21st century agriculture: In the national agriculture systems, we visit farmers' field and provide number of recommendations and advice to the farmers related to varieties, breeds and technologies in isolation. There is need for holistic ways by projecting the whole farm income, expenditure, outcome and activities round the year (Mahapatra and Behera 2011). This is lacking in national agricultural research and extension system. Enterprise/activities combination in farming systems and optimization of scarce resources at the command of farmers must revolve round optimization - optimization enterprise combination and optimization of scarce resource use at farm level fitting to the enterprise combination. These two aspects are weak in national agriculture systems in India and other Asian countries also. This is very important for doubling the farmers income in our country. No agency in National agricultural system is equipped to do so. There is need to modify our education/training programme to develop scientific and skilled manpower in this area.

The Developmental Farm Model (DFM): To help bring agricultural growth to the rural areas of South Asia and in keeping with the millennium goal of reducing world poverty by 50% by 2020, we advocate another model namely the

DFM (Behera *et al.* 2013, Behera and France 2014). This is a holistic farm model that assures adequate income generation and family employment opportunities for the farmer, particularly resource-poor, small-holder farmers, thereby helping to reduce poverty and improve livelihood. It is based on a bottom-up approach and is applicable to all classes of farmer to meet their multi-objective needs. Whether they are subsistence or corporate farmers, this model can help them achieve their desired objectives. The use of optimization methodology (e.g., linear programming and its variants) helps enhance the application of DFM in an efficient way.

The vision behind the DFM concept is to provide the farmers of South Asia and other developing regions with the opportunity to have their own model of development. This takes full account of the fact that all farms are not alike. Hence, with the DFM approach, we visualize providing each and every farmer with a model of their farm for their development.

DFM serves as a powerful capsule for helping cure the multiple problems of agriculture at the farm level. The ingredients of the capsule might be the energy component, soil health improvement by developing a soil health card, farm mechanization to reduce drudgery, value addition, etc. Farm activities can be planned simultaneously to produce renewable energy, generate income and minimise risk by introducing different enterprises, achieve food security and maintain biodiversity and prevent erosion by way of planting trees, shrubs, etc. This creates ecosystem awareness by encouraging diversity at the farm level and redesigning the farming system. Thus, by implementing the DFM approach, aspects/issues such as income generation, risk minimisation, climate change, ecosystem service and energy security can all be well addressed, which is difficult to achieve using conventional approaches.

Energy Self-sufficient Integrated Farming Systems (E-IFS): The question arises as to how and what forms of renewable modern energy generating capacity can be added to the existing resource recycling capabilities of an IFS so that the whole system becomes self-sufficient or even surplus in energy (Behera *et al.* 2013). In the E-IFS concept, the objective is to integrate all direct and indirect sources of energy (which so far have not been fully explored), and to utilize resource recycling and resource conservation to reduce the energy embodied in inputs such as fertilizers, pesticides and irrigation water. This would lead towards a reduction in carbon emissions (i.e. towards carbon neutrality) and cleaner and greener farming.

An E-IFS would be one that uses little or no fossil fuel energy and even produces more energy than is required, so that it becomes another product off the farm. However, such an energy surplus needs to be achieved without competing with food crops for land and resources. Finally, the very nature of farming within an E-IFS, with its diversity of enterprise, can act as a risk reduction mechanism in the wake of climatic changes that may possibly lead to crop failure. The incorporation of modern energy sources within

an IFS can provide an ideal farming system if some of the limitations mentioned previously are overcome. Next we briefly address some policy measures that could make such a system attractive to farmers under current Indian circumstances (Behera *et al.* 2015).

Farm development card: The system view is a useful conceptual device for all concerned with agriculture as it helps researchers understand the context of their research and in defining its content, thus contributing to its relevance. It helps them see their specialization in perspective and in relation to other forces and creates a better climate for cross-disciplinary work. It has been demonstrated that research programmes based on the traditional approach (i.e. commodity based) are not wholly sustainable, equitable and stable over a long period (Behera and France 2016). Doubling the farm income by 2022 is a major challenge before National Agricultural Research System, which can be achieved through large-scale promotion of agro-entrepreneurship by small and marginal farmers, who constitute more than 85% of the farming community, and by the rural youth. For the sustainable development of small and marginal farmers in India there is need of system and holistic approach, which can better achieved with the help of farm development card (Behera and France 2016).

Farm development card (FDC) is a business plan for the farmers which is based on holistic concept of farm development – which considers overall situations of the farm including the knowledge and skill possessed by the farmer and activities needed to achieve the farmers goal within the physical, biophysical and socio-economic and institutional forces under which the farmers operate (Behera 2018a). Farm development card also accommodates soil health card. Hence, beyond soil health card farm development card can better address the farmers' problem and double the farmers' income. FDC includes the following vital components (Behera 2018b): (i) Ecological development, (ii) Economic development, (iii) Energy security, (iv) Enhancing water productivity, (v) Soil health management and (vi) System productivity and sustainability. In addition, FDC considers the farmers resource availability, constraints and market opportunity. For development of FDC, the procedures - (i) Collecting preliminary information, (ii) Formulation of FDC, (iii) Revalidation of the plan to know the feasibility (iv) Implementation of the Farm Development Card and (v) mid-term correction of the plan are followed.

Empowering farmers and entrepreneurs: For promotion of IFS, it's essential that farmers are empowered with knowledge, skill and entrepreneurship. Subsistence agriculture does not generate enough income for the farmers and rural families due to which they are forced to leave farming. Farmers and rural youth will prosper when they are empowered with the required knowledge, skill and entrepreneurship and are connected to value addition economic activities in the agri-business domain. Within the farming systems, there is a need to train the farmers for management of enterprises like dairy, poultry, fishery, mushroom farming etc. and about modern technology/

methods for 'Per Drop More Crop', techniques to take up organic farming, scientific design of an IFS etc.

Synergy through collaboration and linkages: In India, for accelerating agricultural growth, key lies with exploring synergy through collaboration and linkages. We have developed vast infrastructure in our country in comparison to other countries. We have around 703 Krishi Vigyan Kendras, 343 zonal research centres, around 100 farming system research centres (network of AICRP on IFS), vast agricultural line departments and more than 29000 ATMA workers. All are mandated to improve farming systems and benefit farmers. It is seen that they work in parallel lines and hardly collaborate and converge. Now, time has come we should think how to get better output from the vast infrastructure we have developed. This is possible through exploring synergy by linkages and collaborations.

Prescriptive agriculture: Many sick farms of the country need a proper recommendation for corrective measures in the way of prescription. However, even after more than 6 decades of our efforts in agricultural development, we advice farmers mostly orally without handing over a prescription as a doctor does when a patient consults him. It is observed that our National agricultural systems is not properly equipped to do so. Providing a prescription to the farmers may build mutual confidence and strengthen partnership, which is very important from farmers, development point of view.

Conclusion

Farming system approach to research/extension and development is recognized as a potential tool for management of the vast natural resources in developing countries and to meet multiple demands, e.g. supporting livelihood, conserving biodiversity, off-setting emissions, adapting to climate change. An integrated farming system (IFS) represents multiple crops (cereals, legumes, tree crops, vegetables, etc.) and multiple enterprises (livestock production, fish farming, bee keeping, etc.) on a single farm. Promotion of IFS is important for establishing sustainable agriculture. IFS provides scope for exploring synergistic interactions of the components of farming systems, and to enhance resource-use efficiency and recycling of farm by-products. The innovative approaches, DFM, E-IFS, FDC, prescriptive agriculture, synergy through collaboration and linkages and farmers, empowerment are the keys to promote IFS in Indian agriculture.

REFERENCES

- Ahlawat S P S, Mandal A B and Pramanik S C. 2002. Integrated crop-livestock fish farming system for sustained production – Bay island perspective. (In) Proceedings of the National Symposium on Agriculture in Changing Global Scenario. (Eds) Gautam R C, Mishra B N, Shivkumar B G, Rai R K, Mishra S K and Garg R N. Indian Society of Agricultural Sciences, New Delhi.
- Amjath-Babu T S and Kaechele H. 2015. Agricultural system transitions in selected Indian states: What do the related indicators say about the underlying biodiversity changes and economic trade-offs? *Ecological Indicators* **57**: 171–81.
- ASG. 2015. *Agricultural Statistics at a Glance 2014*. Oxford University Press, New Delhi, India.
- Ayyappan S and Arunachalam A. 2014. [Crop Diversification for Social Security of Farmer in India], pp. 1-6. (Eds) Rana D S and Singh A K). Indian Society of Agronomy, New Delhi.
- Behera U K, Rautray S K and Sahoo P K. 2010. Farming system-based composite pisciculture in harvested pond water under eastern Indian situations. *Journal of Soil and Water Conservation* **9**: 143–7.
- Behera U K, Yates C M, Kebreab E and France J. 2008. Farming systems methodology for efficient resource management at the farm level: an Indian perspective. *Journal of Agricultural Science, Cambridge* **146**: 493–505.
- Behera U K. 2018a. Development with Farm Development Card. *ICAR News* **24**(2): 4–7.
- Behera U K and France J. 2016. Integrated farming systems for the livelihood security of small and marginal farmers in India and other developing countries. *Advances in Agronomy* **138**: 235–82.
- Behera U K and Mahapatra I C. 1999. Income and employment generation of small and marginal farmers through integrated farming systems. *Indian Journal of Agronomy* **44**(3): 431–9.
- Behera U K and France J. 2014. Developmental Farm Model for revolutionizing agricultural growth. *ICAR News* **20**(3): 5–6.
- Behera U K, Babu A, Kaechele H and France J. 2015. Energy self-sufficient sustainable integrated farming systems for livelihood security under a changing climate scenario in an Indian context: a case-study approach. *CAB Reviews* **10**(19): 11.
- Behera U K, Bhargavi B, Meena S L, Bhattacharyya R, Singh R, Singh R K, Singh V K, Gupta N and Rana K S. 2018. Research Bulletin on Integrated farming system model for livelihood security of small and marginal farmers. Division of Agronomy, Indian Agricultural Research Institute.
- Behera U K, Choudhary A K, Dass A and Vyas A K. 2013. Integrated Farming Systems for Livelihood Security of Small and Marginal Farmers. Division of Agronomy, Indian Agricultural Research Institute 327 p.
- Behera U K, Sharma A R and Mahapatra I C. 2007. Crop diversification for efficient resource management in India: Problems, prospects and policy. *Journal of Sustainable Agriculture* **30**(3): 97–127.
- Upadhyay P K, Rajanna G A, Sepat S, Bana R S, Choudhary A K, Singh T, Singh R K, Rathore S S, Kumar D, Nath C P, Shiva Dhar, Ghosh P K and Yadav R L. 2018. Doubling farmers' income through agronomic interventions under changing scenario. (In) Extended summaries of XXI Biennial National Symposium. Indian Society of Agronomy, IARI, New Delhi 110 012, p 652.
- Behera U K, Jha K P and Mahapatra I C. 2004. Integrated management of available resources of the small and marginal farmers for generation of income and employment in eastern India. *Crop Research* **27**(1): 83–9.
- Bianchi F J J A, Mikkos V, Brussaard L, Delbalre B and Pulleman M M. 2013. Opportunities and limitations for functional agrobiodiversity in the European context. *Environmental Science Policy* **27**: 223–31.
- Borthakur A and Singh P. 2013. History of agricultural research in India. *Current Science* **105**: 587–93.
- Chopra K. 1993. Sustainability of agriculture. *Indian Journal of Agricultural Economics* **48**(3): 527–35.
- Dalsgaard J P T and Prein M. 1999. *Integrated smallholder agriculture-aquaculture in Asia: Optimising tropic flows. Nutrient disequilibria in agro-ecosystems: Concepts and case*

- studies* pp. 141-155. (Eds) Smaling E M A, Oenema O, Fresco L O), CABI, Wallingford, UK.
- de Haan C, Steinfeld H and Blackburn H. 1997. Livestock and environment: Finding a balance. FAO/USAID/The World Bank. WRENmedia, Eye, Suffolk, UK.
- Dent J B. 1990. [*Systems Theory Applied to Agriculture and the Food Chain*]. Elsevier, Amsterdam.
- Devendra C and Thomas D. 2002b. Crop-animal interactions in mixed farming systems in Asia. *Agricultural Systems* **71**: 27-40.
- Devendra C, Thomas D, Jabbar M A and Zerbin E. 2000. Improvement of livestock production in crop-animal systems in agro-ecological zones of South Asia. ILRI, Nairobi, Kenya.
- Devendra C. 1997. Crop residues for feeding animals in Asia: Technology assessment and adoption in crop/livestock systems. *Crop residues in Sustainable Mixed Crop/Livestock farming System* pp. 241-267. (Ed) Renard C., CABI, Wallingford, UK.
- Devendra C. 2007. Small farm systems to feed hungry Asia. *Outlook on Agriculture* **36**(1): 7-20.
- Devendra C and Thomas D. 2002a. Smallholder farming systems in Asia. *Agricultural Systems* **71**: 17-25.
- Dhyani S K, Newaj R and Sharma A R. 2009. Agroforestry: Its relation with agronomy, challenges and opportunities. *Indian Journal of Agronomy* **54**(3): 249-66.
- Ehrlich P R and Pingle R M. 2008. Where does biodiversity go from here? A grim business as usual forecast and a hopeful portfolio of partial solutions. (In) Proceedings of the US National Academy of Sciences **105**: 11579-86.
- Evenson R E and Gollin D. 2003. Assessing the impact of the Green Revolution - 1960 to 2000. *Science* **300**: 758-62.
- Falcon W and Naylor R L. 2005. Rethinking food security for the 21st century. *American Journal of Agricultural Economics* **87**(5): 1113-27.
- Gangwar B. 1993. Farming systems research for accelerating agricultural development in less developed countries: A review. *Agricultural Reviews* **14**(3): 149-59.
- Gill M S, Singh J P and Gargwar K S. 2010. Integrated farming systems and agriculture sustainability. *Indian Journal of Agronomy* **54**(20): 128-39.
- IOBC 1983. International organization for biological and integrated control. *Technical bulletin* 16(1):45.
- Jain T C. 2008. New paradigms in agronomic research and development. *Indian Journal of Agronomy* **53**(4): 241-4.
- Jha D. 2003. An overview of farming systems research in India. *Annals of Agricultural Research* **24**(4): 695-706.
- Korikanthimath V S and Manjunath B L. 2009. Integrated farming systems for sustainability in agriculture production. *Indian Journal of Agronomy* **54**(2): 140-8.
- Kumar S and Jain D K. 2005. Are linkages between crops and livestock important for the sustainability of the farming system? *Asian Economic Review* **47**(1): 90-101.
- Kumar S, Shivani and Singh S S. 2013. Sustainable food and nutritional security through IFS. *Indian Farming* **63**(7): 30-36.
- Kumar S, Singh S S, Shivani and Dey A. 2011. Integrated faming system for eastern India. *Indian Journal of Agronomy* **56**(4): 297-304.
- Kumar S, Singh S S, Meena M K, Shivani and Dey A. 2012. Resources recycling and their management under an integrated faming system for lowlands of Bihar. *Indian Journal of Agricultural Science* **82**(6): 504-510.
- Lal R and Miller F P. 1990. Sustainable farming system for the tropics. Sustainable Agriculture: Issues and Prospectives, pp 69-89. R.P. Singh (Ed.) . Indian Society of Agronomy, IARI, New Delhi.
- Lightfoot C, Bimbao M P, Dalsgaard J P T and Pullin R S V. 1993. Aquaculture and sustainability through integrated resources management. *Outlook on Agriculture* **22**(3): 143-150.
- Lightfoot C, Bimbao M P, Dalsgaard J P T and Pullin R S V. 1993. Aquaculture and sustainability through integrated resources management. *Outlook on Agriculture* **22**(3): 143-150.
- Mahapatra I C and Behera U K. 2011. Rice-based farming systems for livelihood improvement of Indian farmers. *Indian Journal of Agronomy* **56**(1): 1-19.
- Maheswarappa H P, Hegde M R, Dhanpal R and Biddappa C C. 1998. Mixed farming in coconut garden: its impact on soil, physical, chemical properties, coconut nutrition and yield. *Journal of Plantation Crops* **26**(2): 139-43.
- Maheswarappa H P, Hegde M R, Dhanpal R, Sairam C V and Singh TV. 2001. Impact of integrated mixed farming systems in coconut garden on coconut yield and economic analysis. *Indian Journal of Agronomy* **46**(1): 56-63.
- Manjunath B L and Itnal C J. 2003b. Farming system options for small and marginal holdings in different topographics of Goa. *Indian Journal of Agronomy* **48**(1): 4-7.
- Manjunath B L and Itnal C J. 2003a. Integrated farming system in enhancing the productivity of marginal rice (*Oryza sativa*) holdings in Goa. *Indian Journal of Agronomy* **48**(1): 1-3.
- Mijatovic D, van Oudenhoven F, Eyzaguirre P and Hodgkin T. 2013. The role of agricultural biodiversity in strengthening resilience to climate change: Towards an analytical framework. *International Journal of Agricultural Sustainability* **11**(2): 95-107.
- Paroda R. 2014. Sustainable livelihoods through agriculture diversification and climate smart agriculture. (Eds.) D S Rana and A K Singh. Indian Society of Agronomy, New Delhi.
- Rangaswamy A, Venkitaswamy R, Purushothaman S and Palaniappan S P. 1996. Rice-poultry-fish-mushroom integrated farming systems for the lowlands of Tamil Nadu. *Indian Journal of Agronomy* **41**(3): 344-8.
- Rathore S S and Bhatt B P. 2008. Productivity improvement in jhum fields through an integrated farming system. *Indian Journal of Agronomy* **53**(4): 167-171.
- Rautaray S K, Das, P C and Sinhababu D P. 2005. Increasing farm income through a rice-fish based integrated farming system in rainfed lowlands of Assam. *Indian Journal of Agricultural Sciences* **75**(2): 79-82.
- Ravisankar N, Pramanik S C, Rai R B, Nawaz S, Biswas T K and Bibi N. 2007. Study of an integrated farming system in hilly upland areas of Bay Islands. *Indian Journal of Agronomy* **52**(1): 7-10.
- Ravisankar N, Subrmani T, Ambast S K and Srivasyava R C. 2010. Enhancing farm income in an island ecosystem. *Indian Farming* **60**(6): 16-9.
- Reidsma P, Tekelenburg T, van de Berg M and Alkemade R. 2006. Impact of land use change on biodiversity: an assessment of agricultural biodiversity in the European Union. *Agricultural Ecosystems and Environment* **114**: 86-102.
- Rhoades R E and Booth R H. 1982. Farmer-back to back farmers: a model for generating acceptable agricultural technology. *Agricultural Administration* **11**: 127-37.
- Sharma A R and Behera U K. 2004. Fertiliser use and option for diversification in rice-wheat cropping systems in India. *Fertiliser News* **49**(12): 115-31.
- Shukla A K, Shukla N D and Singh V K. 2002. Farming system approach for food security and sustained rural economy. *Indian*

- Journal of Fertilizers* 47(11): 55–62.
- Singh G. 2015. Agriculture diversification for food, nutrition, livelihood and environmental security: Challenges and opportunities. *Indian Journal of Agronomy*. 60(2): 172–84.
- Singh K, Bohra J S, Singh Y and Singh J P. 2006. Development of farming system models for the north-eastern plain zone of Uttar Pradesh. *Indian Farming* 56(2): 5–11.
- Singh D P, Singh K P and Yadavika. 1998. Integrated farming systems – a key issue for research education – extension linkages to sustain food security and ecofriendly environment in 21st Century, pp 474-486. (In) Proceedings of the First International Agronomy Congress: Agronomy, Environment and Food Security for the 21st Century , pp. 474-486. Singh P, Prasad R, Ahlawat I P S (Eds.). Indian Society of Agronomy, New Delhi.
- Singh G. 2015. Agriculture diversification for food, nutrition, livelihood and environmental security: Challenges and opportunities. *Indian Journal of Agronomy* 60(2): 172–84.
- Singh J P, Gill M S and Tripathi D. 2007. Development of integrated farming system models for marginal and small farmers. (In) Extended summaries of 3rd national symposium on integrated farming system and its role towards livelihood improvement, pp 51-57. ARS, Durgapura, Jaipur, 26-28 November 2007.
- Yadav R L and Prasad K. 1998. Farming systems research in India: needs and strategies. (In) Proceedings of first international agronomy congress: Agronomy, environment and food security for 21st century (Eds.). Singh P, Prasad R and Ahlawat I P S, pp 333-341. Indian Society of Agronomy, New Delhi.