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Ministry of Agriculture &
Farmers Welfare

Report of the Committee on Doubling Farmers' Income

Volume VI

"Strategies for Sustainability in Agriculture"

A Sustainable Agricultural System Ensures Farmers' Welfare and Secures Farmer's Income

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Document prepared by the Committee on Doubling Farmers' Income,
Department of Agriculture, Cooperation and Farmers' Welfare,
Ministry of Agriculture & Farmers' Welfare.

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Foreword

The country has witnessed a series of concerted discussions dealing with the subject of agriculture. In 1926, the Royal Commission of Agriculture was set up to examine and report the status of India's agricultural and rural economy. The Commission made comprehensive recommendations, in its report submitted in 1928, for the improvement of agrarian economy as the basis for the welfare and prosperity of India's rural population. The urban population was about 11 per cent of the whole, and demand from towns was small in comparison. The Commission notes, that communication and physical connectivity were sparse and most villages functioned as self-contained units. The Commission encompassed review of agriculture in areas which are now part of Pakistan, Bangladesh and Myanmar. The net sown area in erstwhile British India was reported as 91.85 million hectares and cattle including buffaloes numbered 151 million. Almost 75 per cent of the cultivated area was under cereals and pulses, with rice and wheat occupying 46 per cent of the net sown area. The area under fruits and vegetables was about 2.5 per cent and that under oilseeds and non-food crops was about 20 per cent. In the ensuing years, as well known, the country underwent vast changes in its political, economic and social spheres.

Almost 40 years later, free India appointed the National Commission on Agriculture in 1970, to review the progress of agriculture in the country and make recommendations for its improvement and modernisation. This Commission released its final report in 1976. It refers to agriculture as a comprehensive term, which includes crop production together with land and water management, animal husbandry, fishery and forestry. Agriculture, in 1970 provided employment to nearly 70 per cent of the working population. The role of agriculture in the country's economic development and the principle of growth with social justice, were core to the discussions. The country was then facing a high population growth rate. After impressive increase in agricultural production in the first two Five Year Plans, a period of stagnancy set in and the country suffered a food crisis in the mid-1960s. The report in fifteen parts, suggested ample focus on increased application of science and technology to enhance production.

Thirty years hence, the National Commission for Farmers was constituted in 2004 to suggest methods for faster and more inclusive growth for farmers. The Commission made comprehensive recommendations covering land reforms, soil testing, augmenting water availability, agriculture productivity, credit and insurance, food security and farmers competitiveness. In its final report of October 2006, the Commission noted upon ten major goals which included a minimum net income to farmers, mainstreaming the human and gender dimension, attention to sustainable livelihoods, fostering youth participation in farming and post-harvest activities, and brought focus on livelihood security of farmers. The need for a single market in India to promote farmer-friendly home markets was also emphasised.

The now constituted DFI (Doubling Farmers' Income) Committee besides all these broad sectoral aspects, invites farmers' income into the core of its deliberations and incorporates it as the fulcrum of its strategy. Agriculture in India today is described by a net sown area of 141 million hectares, with field crops continuing to dominate, as exemplified by 55 per cent of the area under cereals. However, agriculture has been diversifying over the decades. Horticulture now accounts for 16 per cent of net sown area. The nation's livestock population counts at more than 512 million. However, economic indicators do not show equitable and egalitarian growth in income of the farmers. The human factor behind agriculture, the farmers, remain in frequent distress, despite higher productivity and production. The demand for income growth from farming activity, has also translated into demand for government to procure and provide suitable returns. In a reorientation of the approach, this Committee suggests self-sustainable models empowered with improved market linkage as the basis for income growth of farmers.

India today is not only self-sufficient in respect of demand for food, but is also a net exporter of agri-products occupying seventh position globally. It is one of the top producers of cereals (wheat & rice), pulses, fruits, vegetables, milk, meat and marine fish. However, there remain some chinks in the production armoury, when evaluated against nutritional security that is so important from the perspective of harvesting the demographic dividend of the country. The country faces deficit of pulses & oilseeds. The availability of fruits & vegetables and milk & meat & fish has increased, thanks to production gains over the decades, but affordability to a vast majority, including large number of farmers too, remains a question mark.

The impressive agricultural growth and gains since 1947 stand as a tribute to the farmers' resilience to multiple challenges and to their grit & determination to serve and secure the nation's demand for food and raw material for its agro-industries.

It is an irony, that the very same farmer is now caught in the vortex of more serious challenges. The average income of an agricultural household during July 2012 to June 2013 was as low as Rs.6,426, as against its average monthly consumption expenditure of Rs.6,223. As many as 22.50 per cent of the farmers live below official poverty line. Large tracts of arable land have turned problem soils, becoming acidic, alkaline & saline physico-chemically. Another primary factor of production, namely, water is also under stress. Climate change is beginning to challenge the farmer's ability to adopt coping and adaptation measures that are warranted. Technology fatigue is manifesting in the form of yield plateaus. India's yield averages for most crops at global level do not compare favourably. The costs of cultivation are rising. The magnitude of food loss and food waste is alarming. The markets do not assure the farmer of remunerative returns on his produce. In short, sustainability of agricultural growth faces serious doubt, and agrarian challenge even in the midst of surpluses has emerged as a core concern.

Farmers own land. Land is a powerful asset. And, that such an asset owing class of citizens has remained poor is a paradox. They face the twin vulnerabilities of risks & uncertainties of production environment and unpredictability of market forces. Low and fluctuating incomes are a natural corollary of a farmer under such debilitating circumstances. While cultivation is boundarised by the land, market need not have such bounds.

Agriculture is the largest enterprise in the country. An enterprise can survive only if it can grow consistently. And, growth is incumbent upon savings & investment, both of which are a function of positive net returns from the enterprise. The net returns determine the level of income of an entrepreneur, farmer in this case.

This explains the rationale behind adopting income enhancement approach to farmers' welfare. It is hoped, that the answer to agrarian challenges and realization of the aim of farmers' welfare lies in higher and steady incomes. It is in this context, that the Hon'ble Prime Minister shared the vision of doubling farmers' income with the nation at his Bareilly address on 28th February, 2016. Further, recognizing the urgent need for a quick and time-bound transformation of the vision into reality, a time frame of six years (2016-17 to 2022-23) was delineated as the period for implementation of a new strategy.

At the basic level, agriculture when defined as an enterprise comprises two segments – production and post-production. The success of production as of now amounts to half success, and is therefore not sustainable. Recent agitations of farmers (June-July 2017) in certain parts of the country demanding higher prices on their produce following record output or scenes of farmers dumping tractor loads of tomatoes & onions onto the roads or emptying canisters of milk into drains exemplify neglect of other half segment of agriculture.

No nation can afford to compromise with its farming and farmers. And much less India, wherein the absolute number of households engaged in agriculture in 2011 (119 million) outpaced those in 1951 (70 million).Then, there are the landless agricultural labour who numbered 144.30 million in 2011 as against 27.30 million in 1951. The welfare of this elephantine size of India's population is predicated upon a robust agricultural growth strategy, that is guided by an income enhancement approach.

This Committee on Doubling Farmers' Income (DFI) draws its official members from various Ministries / Departments of Government of India, representing the panoply of the complexities that impact the agricultural system. Members drawn from the civil society with interest in agriculture and concern for the farmers were appointed by the Government as non-official members. The DFI Committee has co-opted more than 100 resource persons from across the country to help it in drafting the Report. These members hail from the world of research, academics, non-government organizations, farmers' organizations, professional associations, trade, industry, commerce, consultancy bodies, policy makers at central & state levels and many more of various domain strengths. Such a vast canvas as expected has brought in a kaleidoscope of knowledge, information, wisdom, experience, analysis and unconventionality to the treatment of the subject. The Committee over the last more than a year since its constitution vide Government O.M. No. 15-3/2016-FW dated 13th April, 2016 has held countless number of internal meetings, multiple stakeholder meetings, several conferences & workshops across the country and benefitted from many such deliberations organized by others, as also field visits. The call of the Hon'ble Prime Minister to double farmers' income has generated so much of positive buzz around the subject, that no day goes without someone calling on to make a presentation and share views on income doubling strategy. The Committee has been, therefore, lucky to be fed pro-bono service and advice. To help collage, analyse and interpret such a cornucopia of inputs, the Committee has adopted three institutes, namely, NIAP, NCAER and NCCD. The Committee recognizes the services of all these individuals, institutions & organisations and places on record their service.

Following the declaration of his vision, the Hon'ble Prime Minister also shaped it by articulating 'Seven Point Agenda', and these have offered the much needed hand holding to the DFI Committee.

The Committee has adopted a basic equation of Economics to draw up its strategy, which says that net return is a function of gross return minus the cost of production. This throws up three (3) variables, namely, productivity gains, reduction in cost of cultivation and remunerative price, on which the Committee has worked its strategy. In doing so, it has drawn lessons from the past and been influenced by the challenges of the present & the future.
In consequence, the strategy platform is built by the following four (4) concerns:

- Sustainability of production
- Monetisation of farmers' produce
- Re-strengthening of extension services
- Recognizing agriculture as an enterprise and enabling it to operate as such, by addressing various structural weaknesses.

Notwithstanding the many faces of challenges, India's agriculture has demonstrated remarkable progress. It has been principally a contribution of the biological scientists, supplemented by an incentivizing policy framework. This Committee recognizes their valuable service in the cause of the farmers. It is now time, and brooks no further delay, for the new breed of researchers & policy makers with expertise in post-production technology, organization and management to take over the baton from the biological scientists, and let the pressure off them. This will free the resources, as also time for the biological scientists to focus on new science and technology, that will shift production onto a higher trajectory - one that is defined by benchmark productivities & sustainability. However, henceforth both production & marketing shall march together hand in hand, unlike in the past when their role was thought to be sequential.

This Report is structured through 14 volumes and the layout, as the readers will appreciate, is a break from the past. It prioritizes post-production interventions inclusive of agri-logistics (Vol. III) and agricultural marketing (Vol-IV), as also sustainability issues (Vol-V & VI) over production strategy (Vol. VIII).The readers will, for sure value the layout format as they study the Report with keenness and diligence. And all other volumes including the one on Extension and ICT (Vol. XI), that connect the source and sink of technology and knowledge have been positioned along a particular logic.

The Committee benefited immensely from the DFI Strategy Report of NITI Aayog. Prof. Ramesh Chand identified seven sources of growth and estimated the desired rates of growth to achieve the target by 2022-23. The DFI Committee has relied upon these recommendations in its Report.

There is so much to explain, that not even the license of prose can capture adequately, all that needs to be said about the complexity & challenges of agriculture and the nuances of an appropriate strategy for realizing the vision of doubling farmers' income by the year of India's 75th Independence Day celebrations.

The Committee remains grateful to the Government for trusting it with such an onerous responsibility. The Committee has been working as per the sound advice and counsel of the Hon'ble Minister for Agriculture and Farmers' Welfare, Shri Radha Mohan Singh and Dr. S.K. Pattanayak, IAS, Secretary of the Department of Agriculture, Cooperation and Farmers' Welfare. It also hopes, that the Report will serve the purpose for which it was constituted.

12th August, 2017

Ashok Dalwai
Chairman, Committee on
Doubling Farmers' Income

About Volume VI

The sixth volume of the Report of the Committee on Doubling Farmers' Income (DFI) examines the actionable strategies and practices to achieve sustainability in agriculture. Sustainability, of productivity and production, is critical in ensuring viability and consistent growth in both farm production and income. Any production system can be considered to be rational, only when it balances the economic interests with the ecological demands.

The DFI strategy which aims not only at doubling farmers' income, but doing so consistently over the long run, adopts sustainable farm practices as an important anchor of its strategy.

The approaches for achieving higher total production from agricultural system through productivity gains, is examined in Volume-VIII of this Report, whereas Volume-V and Volume-VI deliberate upon the necessary sustainability factors. In this way, the following Volume-VII, which concerns with input management, is further an extension on the sustainable approach to agriculture.

While Volume-V dealt with the principles and concepts of sustainable agriculture, and therefore provided details of various issues that encompass the subject, Volume-VI moves forward and translates those ideas into workable models.

It may however be appreciated, that many of the various specific strategies discussed in this volume, are already in practice, both in India and outside, but have unfortunately not made the desired mark. The major challenge, therefore, lies in making them universally accepted practices. This is conditional upon affecting necessary changes to the mind-set of the involved stakeholders, which include farmers, scientist, policy makers, implementation agencies, trade, etc., and for them to recognise this as a value proposition in itself.

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Ashok Dalwai

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Doubling Farmers' Income

Volume VI

"Strategies for Sustainability in Agriculture"

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Chapter 1

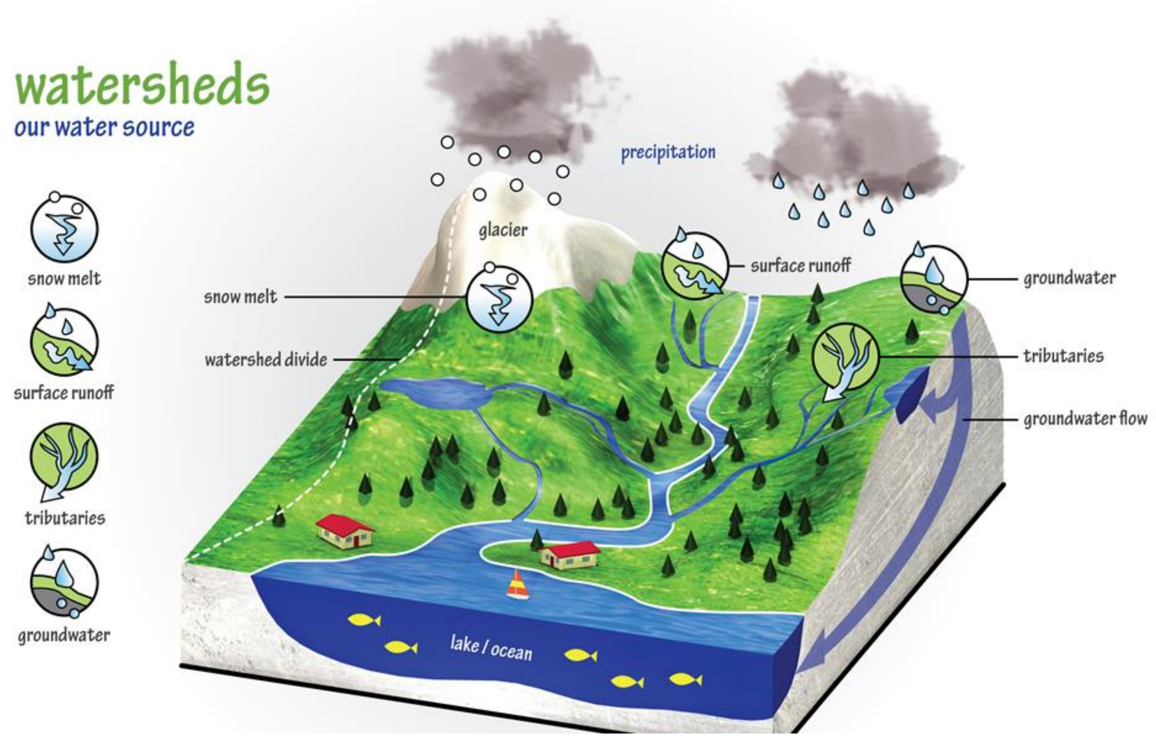
Watershed Management

Watershed management is the study of the relevant characteristics of a watershed aimed at sustainable distribution of its resources and the process of creating and implementing plans, programs, and projects. The purpose is to sustain and enhance watershed functions that affect the plant, animal, and human communities within the watershed boundary with a view to creating jobs and incomes for the welfare of the watershed community.

1.1. Introduction

A watershed is a defined geographic area through which water flows across the land and drains into a common body of water, whether a stream, river, lake, or ocean. The watershed boundary more or less follows the highest ridgeline around the stream channels and meets at the bottom or lowest point of the land, where water flows out of the watershed, the mouth of the waterway. Much of the water comes from rainfall and storm water runoff. The quality and quantity of storm water is affected by all the alterations to the land--mining, agriculture, roadways, urban development, and the activities of people within a watershed. Watersheds are usually separated from other watersheds by naturally elevated areas.

Figure 1.1 A typical watershed model



1.2. Importance of Watershed

Watersheds are important, because the surface water features and storm water runoff within a watershed ultimately drain to other bodies of water. It is essential to consider these downstream impacts when developing and implementing water quality protection and restoration actions. Everything upstream ends up downstream.

Declining soil productivity is a great threat to sustainability in agricultural production. It, thus, calls for optimal utilization of soil resources that can only be affected once land use is made as per capability. Incompatible land use is responsible for inducing degradation processes.

Watershed management is a major land development program in the country. It is essential to introduce **Referencing System of Watershed at National level** as different watershed development programs are operationalized by various departments and ministries. This system will help recognize the watershed by way of national code and avoid duplication on the part of implementing agencies.

Watershed development activities should not be limited to only engineering and vegetative measures as is common. It must ensure sustainability in food production, eco-development and soil health care. More importantly, it is the community that should form the core concern.

All land developmental activities should adopt a holistic approach. Shortcut method for immediate gain through land reclamation will lead to dangerous consequences of land degradation and fragile ecosystem.

1.3. History of Watershed Programme in India

The long history of watershed management and the related policy focus on the subject, since 1960s as recounted below highlights the importance of this approach.

Year / Period	Description
1962-63	Centrally Sponsored Scheme of "Soil Conservation Work in the catchments of River Valley Projects (RVP)" was launched.
1972-73	Conservation work was an ongoing component in the Drought Prone Areas Programme (DPAP) launched by the Ministry of Rural Development (MoRD) in 1972-73
1977-78	MoRD started a special programme for hot desert areas of Rajasthan, Gujarat and Haryana, and cold desert areas of Jammu & Kashmir and Himachal Pradesh, (earlier under DPAP) called Desert Development Programme (DDP).
1980-81	The Ministry of Agriculture started a scheme called Integrated Watershed Management in the Catchments of Flood Prone Rivers (FPR).
1982-83	The Ministry of Agriculture launched a scheme for propagation of water harvesting/conservation technology in rainfed areas in 19 identified locations.
1984	In October, the Ministry of Rural Development (MoRD) adopted the above approach in 22 other locations in rainfed areas.
1980s	Several successful experiences of fully treated watersheds, such as Sukhomajri in Haryana and Ralegaon Siddhi in Western Maharashtra, came to be reported.

Year / Period	Description
1988	National Committee was set up under the Chairmanship of the Member, Planning Commission to appraise and review DPAP and DDP. The Committee was initially headed by Dr. Y.K. Alagh and later by Shri L.C. Jain who took over as Member, Planning Commission in charge of the subject. The Committee submitted its report in August 1990.
1990	With experience gained from all the above interventions, the concept of integrated watershed development was first institutionalised with the launching of the National Watershed Development Programme of Rainfed Areas (NWDPRA), covering 99 districts in 16 states. This was an initiative of the Ministry of Agriculture.
1994	A Technical Committee under the Chairmanship of Prof. C.H. Hanumantha Rao was appointed to appraise the impact of the works done under DPAP/DDP; identification of the weaknesses of the programmes and to suggest improvements. The Committee formulated a set of "Common Guidelines", bringing five different programmes under the MoRD
1994 - 2001	Large number of Watershed Projects were taken up by MoRD between 1994 to 2001, following the adoption of "Common Guidelines of 1994".
2000	In 2000, the Ministry of Agriculture revised its guidelines for NWDPRA, making them "more participatory, sustainable and equitable". These were called WARASA – JAN SAHABHAGITA Guidelines.
2001 and 2003	The Common Guidelines of 1994 were revised by MoRD in 2001, and further revisited and reissued as "Guidelines for Hariyali" in April 2003.

The Hanumantha Rao Committee (1994) opined, that *"the programmes have been implemented in a fragmented manner by different departments through rigid guidelines without any well-designed plans prepared on watershed basis by involving the inhabitants. Except in a few places, in most of the programme areas the achievements have been dismal. Ecological degradation has been proceeding unabated in these areas with reduced forest cover, reducing water table and a shortage of drinking water, fuel and fodder".* The Committee, therefore, decided to revamp the strategy of implementation of these programmes, drawing upon the "the outstanding successes" of some ongoing watershed projects.

It recommended, that sanctioning of works should be on the basis of the action plans prepared on watershed basis instead of fixed amount being allocated per block as was the practice at that time. It called for introduction of participatory modes of implementation, through involvement of beneficiaries of the programme and non-government organisations (NGOs).

It further recommended, that "wherever voluntary organizations are forthcoming, the management of watershed development should be entrusted to them with the ultimate aim of handing over to them one-fourth of total number of watersheds for development".

The Committee also called for substantial augmentation of resources for watershed development by "pooling resources from other programmes being implemented by the Ministry of Rural Development, e.g., Jawahar Rozgar Yojana, Employment Assurance Scheme, etc., and by integrating them with DPAP and DDP".

The Committee recommended suitable institutional mechanism for effecting needed coordination between and among different departments at the central and state levels, with a view to ensuring uniformity of approach in implementing similar programmes for the conservation of land and water resources. On the basis of these recommendations, the Hanumantha Rao Committee formulated a set of "Common Guidelines", bringing five different programmes under the MoRD, namely, DPAP, DDP and Integrated Wastelands Development Programme (IWDP), as also the Innovative- Jawahar Rozgar Yojana (I-JRY) and Employment Assurance Scheme (EAS). It was also laid down, that 50 per cent of the funds under I-JRY and EAS be allocated for watershed works.

1.4. Ongoing Watershed Programmes

In 2017-18, the various programmes being implemented are as follows:

A. Department of Land Resource, Ministry of Rural Development.

i. Drought Prone Areas Programme (DPAP)
ii. Desert Development Programme (DDP)
iii. Integrated Wasteland Development Programme (IWDP)
iv. Externally Assisted Projects (EAPs)
v. Investment Promotional Scheme
vi. Support to NGOs

1.4.1. Types of watershed

Watersheds are classified depending upon the size, drainage, shape and land use pattern.

- Macro watershed (> 50,000 hectares)
- Sub-watershed (10,000 to 50,000 hectares)
- Milli-watershed (1000 to 10000 hectares)
- Micro-watershed (100 to 1000 hectares)
- Mini-watershed (1-100 hectares)

1.4.2. Objectives of watershed management

The multiple objectives of watershed management programmes are:

- To mitigate the adverse effects of drought on crops and livestock
- To control damaging runoff and degradation and conserve soil and water.
- To manage and utilize the run-off water for production purpose.

- To protect, conserve and improve the land within a watershed more efficiently and realise sustained production.
- To protect and enhance the water sources originating in the watershed.
- To check soil erosion and to reduce the effect of sediment yield on the watershed.
- To rehabilitate the deteriorating lands.
- To moderate the flood peaks at downstream areas.
- To increase percollation and infiltration of rainwater into the soil.
- To improve and increase the production of timber, fodder and wild life. To enhance the ground water recharge, wherever applicable.

1.4.3. Components of watershed

A combination of engineering and agronomic practices is adopted in watershed treatment. More importantly, a watershed intervention seeks to build a stake for all inhabitants, and offer them sustainable livelihood options. Broadly, an action plan for treatment comprises:

- Engineering interventions – land levelling, drainage line works, contour bunding (using stones & gravel), contour trenching, soak pits, check dams, diversion weirs, ponds & tanks etc.
- Agronomic interventions – vegetative contour bunding, crop alignment, agro-horti-forestry, silvi-pasture, mulching, crop alignment etc.
- Non-farm activities – in order to supplement the farm incomes of the cultivators and also provide job opportunities through allied & ancillary activities for the landless, enterprises like dairy, poultry, fishery, tiny & cottage processing units etc. are promoted. The resources for such activities are linked to farm and common property resources (forests, water bodies etc.). Necessary skill is also imparted.

Watershed essentially is a people-centric initiative. Hence, the desired focus has to be on mobilization of the inhabitants to accept and own the watershed. This deserves the highest attention and has generally been the weakest link, and rather the most challenging.

1.5. Factors affecting Watershed Management

1.5.1. Vegetative cover

It is an important landscape element in any watershed. The distribution of vegetation species may be diverse and highly variable across the watershed, but vegetation communities can be described in more general terms as well. Drainage density can affect the shape of a river's hydrograph during a rain storm. Rivers that have a high drainage density will often have a more 'flashy' hydrograph with a steep falling limb. High densities can also indicate a greater flood risk.

1.5.2. Climatic characteristics

The greatest factor controlling stream flow, by far, is the amount of precipitation that falls in the watershed as rain or snow. However, not all precipitation that falls in a watershed flows out, and a stream will often continue to flow where there is no direct runoff from recent precipitation. The amount of rainfall affects the flow of the streams within the watershed area, and ultimately the quantity of water that is stored in the watershed.

1.5.3. Watershed characteristics

The shape of the watershed contributes to the speed with which the runoff reaches a river. A long and narrow catchment will take longer to drain than a circular catchment. Basin shape is not generally used directly in hydrologic design methods. Watersheds have an infinite variety of shapes, and the shape supposedly reflects the way that run-off will "bunch up" at the outlet. A circular watershed would result in run-off from various parts of the watershed reaching the outlet at the same time. An elliptical watershed having the outlet at one end of the major axis and having the same area as the circular watershed would cause the run-off to be spread out over time, thus producing a smaller flood peak than that of the circular watershed. The size helps determine the amount of water reaching the river, as larger the catchment the greater the potential for flooding. Topography determines the speed with which the run-off will reach a river. Clearly, rain that falls in steep mountainous areas will reach the primary river in the watershed faster than in case of flat or lightly sloping areas. Topographic maps show lines of equal elevation. Watershed slope affects the momentum of run-off. Both watershed and channel slope may be of interest. Watershed slope reflects the rate of change of elevation with respect to distance along the principal flow path. It is usually calculated as the elevation difference between the end-points of the main flow path divided by the length. The elevation difference may not necessarily be the maximum elevation difference within the watershed since the point.

1.5.4. Contributors to water pollution

Common contributors to water pollution are nutrients and sediment which typically enter the stream systems after rainfall washes them off the poorly managed agricultural fields, called surface run-off, or flushes them out of the soil through leaching. These types of pollutants are considered non-point source pollution, because the exact point where the pollutant originated cannot be identified. Such pollutants remain a major issue for water ways, because the difficulty to control their sources hinders any attempt to limit the pollution. Point source pollution originates a specific point of contamination, such as failure of a manure containment structure and its contents entering the drainage system or when a factory discharges its waste directly into a body of water using a pipe.

1.6. Management of Watershed

1.6.1. Crops and system management

Crop rotations are required for optimal utilization of land to feed ever increasing population and are useful in reducing pest and disease problems, reducing weed pressure, reducing soil erosion, building organic matter, and supporting a diverse soil microbial community. Rotations that include several crops of different plant families support better soil health than simpler rotations. A diverse crop rotation that includes legumes and deep rooted crops can enhance an efficient cycling and utilization of crop nutrients. On sloping land, integrating a conservation crop rotation with other practices such as strip cropping or contour buffer strips can greatly reduce soil erosion and protect soil health. This includes cover crops, green manures, catch crops in single season crop and alley cropping, inter-cropping, hedgerows, etc., for perennials

1.6.2. Agro-forestry

The single crop areas having saline water (ground water quality) in the block are the best sites for the adoption of the Agro-forestry (with salt tolerant spp.). The concept of Agro-forestry implies the integration of annual crops with perennial trees on the farm to the benefit of the agriculture system. This concept originated from realisation of the fact, that the trees play a vital role in safeguarding the long term interest of the agriculture, and in making farm economy viable. Trees can be incorporated within a farming system by planting them on land which is not suitable for crop production. Trees help to preserve the fertility of the soil through the return of organic matter and fixation of nitrogen. As a result, less run-off is generated and erosion is better controlled. Agro-forestry system requires careful selection of both crop and tree species if a beneficial interaction is to be obtained. Species recommended for agro- forestry in the area include:

Peripheral planting/ hedges row

It consists of one or more lines along the field boundaries in all directions. It has been observed that trees, even when they are grown along the bunds and water channels in the field, conserve soil moisture, improve soil fertility, protect field crops against scorching heat & winds making the climate more hospitable and supporting better yield outputs. This practice is generally suggested for situations having large single cropped areas.

Silvi-pasture or fodder development

The Silvi-pasture is one such alternative land use system available for improving the fodder resources of the area. This system offers an extra yield of grass during the rainy season. The demand for fuel wood and fodder is ever increasing in the rural sector due to increase in human & livestock population resulting in indiscreet tree felling. In order to make the region ecologically sustainable and reduce the pressure on forest land, there is a need to develop the degraded pastures / grazing lands available near the villages, by cultivating species which are native to the area.

A few leguminous species may also be grown along with grasses, which will contribute to soil nutrition through nitrogen fixation. It is also suggested, that the local forest species may also be planted along with grasses as an additional source of fuel and fodder.

Agri-horticulture/Orchard plantation

In the rainfed areas across different regions of the country characterised by arid, semiarid and sub humid conditions large tracts of agricultural lands continue to be mismanaged, subjecting them to degradation. Desertification and erratic rainfall characteristics of these regions makes crop production risky and non-remunerative, apart from causing serious imbalance in the ecosystem in long run. Adoption of new, innovative and efficient alternative methods can make the lands more productive on sustainable basis. Interspersing the present cropping systems with a few suitable tree species is one such beneficial land use system. The growing of trees helps in controlling soil erosion, improving soil fertility and increasing soil moisture retention capacity. Hence, the concept or Agri-horticulture i.e. growing of the fruit trees in combination with agricultural crops has been recommended for these areas. The judicious management of trees and crops results in optimal use of soil and water resources and ultimately leads to sustainable productivity of the land. Agri-horticulture with soil conservation measure is a good practice in areas where slope is a limitation i.e. 3 to 5 per cent. Bushes and small size trees like ber (*Ziziphus mauritiana*) are suggested.

Horticulture

The fruit trees possess enormous resilience to harsh conditions. Besides, the trees effectively utilize off-season rains which otherwise go waste, and also serve as a source of firewood, as their dried twigs and branches can be used for this purpose. Drip irrigation system is recommended for efficient water management horticultural plantation. Another approach for irrigation could be channelling of water from surrounding areas in to saucer shaped pits around trees. Training and pruning of trees is essential for getting higher fruit yield. Fruit trees need to be supplemented with farm yard manure and balanced fertilizers every year. Insect, pest and disease control measures have to be undertaken as per need. In addition to these routine management practices, some additional techniques like water harvesting have to be adopted wherever necessary and feasible. Agri-horticultural cropping systems provide an effective opportunity to expand area coverage under horticulture.

Diversification in watershed

Diversification is integral to a watershed, as it aims at optimal utilization of the natural resources. Since water bodies constitute an important intervention, fishery along with bund cultivation can be promoted, depending upon the quantity and time period over which water is stored. Integrated farming is a risk negotiation farming practice, particularly for the small and marginal farmers. Hence, diversification into livestock, poultry, etc. along with agriculture and horticulture serve the twin purpose of more than one source of income and optimal utilization of natural resources on a watershed basis.

Water management

Watershed management is based on the principle of ridge to valley treatment, leading to effective conservation of soil & water conservation, which two are the basic resources for an agricultural system. It would be useful to adopt "clustered approach" on large scale to optimise water use. The clustering *by definition is a "geo-hydrological unit" comprising clusters of micro-watersheds as the new unit for planning and where assessment and intervention are planned on the on landscape level, with a focus on* *hydrological resources*.

The first and foremost step is to form clusters based on to "multi-tier" sequencing of watershed development, beginning with upper reaches or forests "where the water sources originate", followed by "the second tier" or intermediate slopes just above the cultivable lands, and then the "third level" or plains/flat areas "where typically farmers cultivate." It also refers to the standardized phasing of the Watershed Development Projects into three phases: preparatory, works, and consolidation and withdrawal priorities for water resources management.

1.6.3. Implementing agencies

The watershed programme is being carried out in desert, drought prone and rainfed areas through DRDA/Zilla Parishad at the district level. Project implementation agency is also selected by DRDA / Zilla Parishad. However, other institutions like Integrated Tribal Development Agencies (ITDAs), agricultural universities, research institutions, government undertakings, non-governmental organisations etc. are also entrusted with some watershed projects for implementation. Not for profit organisations also take up independent work with supporting contribution from private sector.

1.6.4. Beneficiaries

a. Local residents inside the of the watershed area.
b. Poor families specially SC/ST persons in rainfed areas where economic status of the people is relatively vulnerable due to problems of lower production, scanty rain and degradation of land.
c. Members of self-help groups (SHG).
d. Landless persons who are given usufruct rights over assets created on common property resources (CPRs).

1.6.5. Production activities - cropping pattern

- Introduction of suitable crops, improved crop varieties, inter-cropping, contour cultivation and crop management practices
- Sericulture
- Horticulture
- Livestock development fodder cultivation, milch cattle distribution, establishment of milk co-operatives
- Integration of other activities such as sheep rearing, fisheries, piggery, poultry, bee-keeping etc.

1.6.6. Employment generation activities

- Creating more employment through land based and productive activities.
- Raising backyard nurseries.
- Wage earning through community assets creation such as community buildings, village roads etc.
- Cottage industries based on bamboo, wood craft, cane craft etc. by using natural resources generated on the farm and over CPRs.

1.6.7. Case study - example from Rajasthan

Phagi block in Rajasthan has seen concerted efforts on rainwater management over the past decade. Private sector initiatives, on rainwater management has led to holistic village development, livelihood enhancement and income generation in twenty five (25) villages in Phagi. The work undertaken by Advit Foundation, a not for profit development organisation, focuses on conservation of environment resources and livelihood enhancement. The primary interventions involved the creation of more than 2,00,000 cubic metres of water storage in Phagi block, through 17 water conservation structures:

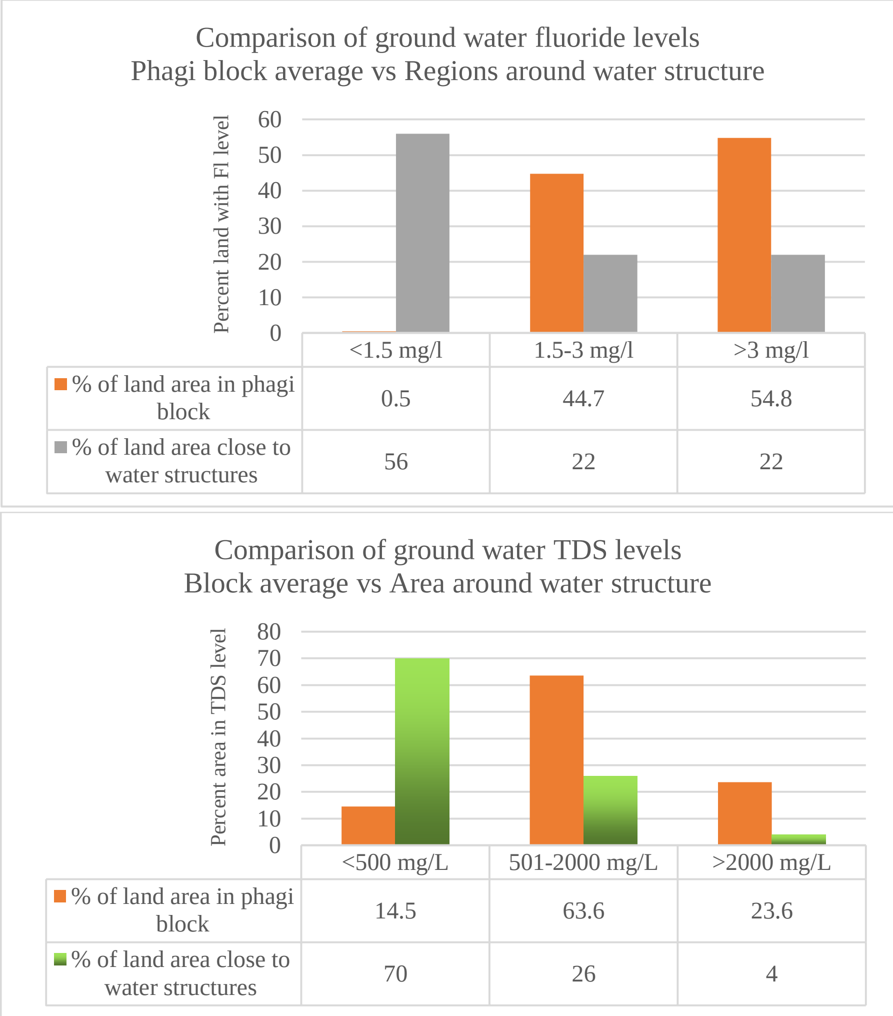
- Bheempura 6,000 cu m
- Keeratpura 6,000 cu m
- Sanwal 6,000 cu m
- Chandawas 6,000 cu m
- Nawal Kishorpura 6,000 cu m
- Awandiya 24,000 cu m
- Jhodinda Bhojpura 15,000 cu m
- Sawa Ka Bas(2 structures) 30,000 cu m + 10,000 cu m
- Pachala (2 structures) 50,000 cu m +12,000 cu m
- Awandiya (Gawario ki Dhani) 4,950 cu m
- Sultaniya (Musalmano ki Dhani) 4,950 cu m
- Sultaniya 7,500 cu m
- Bookni 6,000 cu m
- Govindpura Basra 6,000 cu m
- Bhankrota 6,000 cu m

Around each water structure, wells have got recharged and at least 10 wells are monitored for results. Another outcome has been that the levels of salinity and fluoride in groundwater has reduced. Phagi area is predominantly contaminated with fluoride as per the central ground water repor, with average fluoride concentration of 1.5mg/l. However, recent measurements show that the fluoride concentration has decreased to 0.6mg/l in the wells near the built water structures (tests in 2016 show village Sawa Ka Bas: 0.75mg/l, Basra: 0.6mg/l, Pachala : 0.6mg/l, Bhankrota: 0.6mg/l).

More than 70 per cent of the wells and bore wells near the constructed water structures now have potable water (i.e. less than the accepted 500mg/l TDS value by BIS standards), a major improvement compared to only 14.5 per cent in rest of Phagi block. Ground water level has also improved in this period, and in areas close to the water structures, the ground water is now available between 3 to 12 metres below surface.

Tree plantation was undertaken, with 50 to 80 trees surrounding each water structure. There are indications that this has an impact on increasing humidity levels and can also lead to a drop in ambient temperatures. The structures have ensured water availability for drinking, sanitation, agriculture and livestock.

Figure 1.2 Impact of water structure on ground water quality



Importantly, due to post-rainwater accumulation in the structures, the soil moisture content has increased in surrounding areas. This has improved production in traditional crops sown in July, and shown a doubling of the production from October sowing. For instance, in village Pachala black gram production per acre of land has increased from 8 quintals to 16 quintals. Water availability has also allowed sowing other crops like mustard, fennel and cumin.

Water structures and increase in agriculture

The following have been the key impact indicators of the interventions as observed in 2016:

i. Area expansion: close to 50 per cent increase in agricultural land use, adding area that was earlier lying barren.

ii. Productivity: winter crop yield has doubled over the last 5 years. In village Pachala, black gram production increased from 8 quintal to 16 quintals per acre (2016-17).

iii. Cropping intensity: the communities now grow two crops in a year (July and October) as compared to only one, previously sown in July.

iv. Diversification: farmers have started cultivating cash crops such as mustard, cumin, fennel which has added a new source to their income.

v. Livestock yield: the number of cattle and their yield has gone up by at least 10 per cent in the villages.

Other impact in areas of secondary agriculture activities (cottage scale enterprise using local resources) resulting from yield growth, livestock, diversification and agro-foresting:

a. Water availability has reduced drudgery on women folk who have taken up cloth and paper bag making, as an economic activity.

b. Primary cleaning and packaging of local produce (spices, cumin, red chilli, coriander, etc.) is now being taken up.

c. Bio-gas installations are being set-up to use dung efficiently (about 5 households per village). This allows households with about 3 to 4 cattle to generate cooking gas – LPG cylinders have not been bought by these homes since 2016.

The sustainability of the interventions is measured and ensured through other activities to maintain and conserve environment resources which is leading to economic empowerment and climate proofing in the block. The activities by Advit Foundation are carried out with private sector participation through contributing resources and CSR funds.

1.7. Strategy for Soil and Water Conservation

The Division of Natural Resource Management (NRM) in DAC&FW, Government of India adopts micro-watershed as a basic unit of treatment with a view to developing the land resources under natural system in the catchments of River. The policy of the department is to treat the most vulnerable micro-watersheds on priority basis based on scientific data base, dissemination of data base to the implementing agencies and monitoring the progress of the developmental activities. The strategy adopted by the Department comprises:

- Dissemination and adoption of National Level Micro-Watersheds developed by dedicated organizations.
- Use of detailed scientific soil, land and water information generated on high spatial resolution for planning of vulnerable areas under watersheds.
- Integration of baseline survey maps for development of integrated action plan for development of each micro-watersheds.
- Awareness campaign and peoples' participation in watershed management.
- Evaluation of the impact of watershed development program.

1.7.1. Detailed scientific base line survey

Systematic watershed management essentially requires baseline survey for scientific data collection, comprehensive assessment, interpretation and analysis of area of interest and adoption of integrated approach. Currently, watershed information in the country is trapped in many different databases generated by many governmental agencies located across the country. These include:

- Survey of India stores data on Land topographic information.
- National Remote Sensing Centre (NRSC), under the Department of Space has information of terrain and land use / cover etc.
- Central Ground Water Board hosts data on water quality assessment.
- Central Water Commission (CWC) monitors water quantity under hydrometric program.
- Department of Land Resources under the Ministry of Rural Development is the repository of data on degraded lands.

Soil and Land Use Survey of India (SLUSI), under DACFW is responsible for development of referencing system for micro-watershed and generation of detailed soil and land use related database at 1:10,000 scale using high resolution satellite data on GIS and GPS platform. The baseline survey work involves collection, interpretation, and dissemination of soil, land, and water data and information.

1.7.2. Baseline survey (Survey Scale 1:10,000)

These baseline surveys help in assessing the real potential of individual resource on real time basis using geo-spatial technology. These final maps contain the information of related attributes of the above mentioned subjects with its class showing the level of degradation or conservation in the ecosystem. To prepare a scientific action plan, following list of maps will be required for integration of the survey data and map data on a suitable platform.

The baseline survey should include the status of socio-economic conditions, soils, present land use, production systems in practice, productivity, cropping intensity, cropping pattern, crop rotation etc., wastelands, horticulture, hydrology and water resources, ground water quality, ground water depth, ground water prospectus, forests and grass land, livestock and fisheries, livelihood status, soil and moisture conservation efficient use of water, problems and needs. The map scale of (1:10,000) can host components of index map of watershed, watershed map, drainage map, slope map, soils map, land capability class map, cropping pattern, crop rotation, cropping intensity map, wasteland map, horticulture crop map, hydrology and water resources, ground water prospectus, ground water quality, ground water depth, forests and grass land, map showing existing conservation measures, any other map and proposed action plan map.

1.8. Action Plan for Integrated Watershed Management

The Common Guidelines for Watershed Development Projects lay down a pragmatic approach to resolving issues of "institutional" versus "natural" boundaries by defining "operational watersheds" that align largely to village boundaries. This tactic - based on socially, politically, and/or administratively meaningful units—has been successfully applied. **Since the watershed**

program is primarily a social program, and also because Village Watershed Committees (VWCs) within each Gram Panchayat are to be the ultimate implementing agency, the Guidelines offer a practical management solution.

Under the new program, cluster approach is followed with a broader vision of natural hydro-geographical unit of an average size of 4,000 to 8,000 ha. comprising clusters of micro-watershed or one sub-watershed which will be selected as project area and the information is presented *according to the village boundaries, to which sub/micro*-watershed *boundaries are to be approximated. All thematic map and table will be presented of the draft will be on the cluster identified as group of villages. The tabular data furnish the area information of selected cluster village wise.*

1.8.1. Key components of action plan

Multi-tier approach
There should be a multi-tier ridge to valley sequenced approach, in watershed treatment. The higher reaches or the forests are the locations where the water sources originate. The approach, therefore, will be to identify forest and the hilly reaches, in the upper water catchments. The forest areas are best treated with support from forest department. It is necessary to plan and execute the minimum engineering treatments beginning with the ridge and ending at the valley. Since the purpose would be to check run off of both soil and water, appropriate interventions would include drainage line treatment, contour bunding, soak pits etc. and small ponds, water harvesting structures etc. depending upon the gradient and harvestable water. The following year should be one of adopting agronomic practices. This includes planning for cropping system based on the classification of land. Only those that are Class IV (as per USDA land classification system) and below may be brought under field crops with appropriate treatment, and reserve the upper reaches for miscellaneous plantations including horticulture species.

Community participation
The basic characteristic of watershed approach is collective action. Conservation of both soil and water calls for collective and collaborative effort of all the farmers and landless agricultural labour who depend upon the defined region. In the first place, the degradation of a delineated watershed is the result of unscientific and indiscreet engagement by both the landed and the landless with the watershed resources.

The common properties including the forests, wastelands and waterbodies may have been over-exploited, either due to the density of human & animal population or by sheer carelessness. The individual assets including the cultivated farms may not have been used as per the carrying capacity of the land or with no measures needed. It is critical to realise, that each of these private (farmers' land parcels) and common property resources are organically linked with one another, the resource conservation and enrichment entails collective effort both at treatment stage, and during the maintenance phase. In fact the latter phase constitutes a continuing phenomenon.

It is, therefore, critical to mobilise all members who represent the watershed and more importantly build a stake for them in its maintenance. The stake for all of them consists of:

i. realising that the carrying capacity of the watershed depends upon the status of soil & water, and its ability to sustain a certain level of productivity;
ii. farmers owing land benefit directly because improved soil & moisture status can sustain crop production better;
iii. the landless benefit from the ability of the common property resources like forests, grazing lands, regenerated wastelands and water to produce fodder, fuel, timber, minor forest produce etc. and enable them to find non-farm job and income avenues.

It is only when, each understands the stake that he has in the wellbeing of the watershed, that he can be motivated to contribute to its treatment and sustenance. The corollary of the above comprehension is the need for building appropriate institutions, which will enable each member to channelize his contribution. It may simply involve taking care of the contour bunds or practising crop alignment (in consonance with soil, water & other agro-climatic demands) by the farmers; or restricting oneself to using the forest, grazing and water resources by both the cultivators and the landless in consonance with sustainable practices and laid down norms.

For practice of such constructive response on the part of all members, it is important to build various interest groups like:

- watershed members association
- water users association
- cattle owners association
- forest management group
- self-help group
- farmer producers organisation
- commodity interest group

Further, the members need to be supported in upgradation of their individual:

- information, knowledge & skill base: and
- management of institutions

A pre-requisite, therefore, to a successful treatment on watershed basis is the mobilization of the members, organisations, institutions and capacity building. The experience of watershed management in the country over the last 4 decades is, that "there can be no success without community participation". Most watershed treatments are seen to be characterised dominantly by engineering works, as they are mostly carried out by the soil conservation departments and construction is always an easier activity. Of course, it is another matter, that these very same works are not maintained post-the completion.

A key parameter of success is assessing the performance of a watershed in terms of change in the agronomic practices adopted by the farmers. An important component of this is the crop alignment. Hence, both attitudinal changes vis-a-vis the desired cropping plan and imparting appropriate knowledge & skills to take new technology and farm management practices hold key to long term sustenance of watershed. An important component, arising from income approach to agriculture, is to enable the farmers to capture the true value of the produce. Some interventions needed are:

- primary processing at farm gate;
- aggregation of the lots; and
- availing of best market options
  - direct market
  - online trade

This post-production support has generally not been considered in watershed management. This cannot be wished away, for enhanced incomes will serve as an incentive to take care of the treated watershed with the desired level of involvement.

1.8.2. Capacity building of the PIA

The officials who constitute the Project Implementation Agency (PIA) need orientation and training in management. Normally, a PIA is set up by pooling of officers with the needed expertise in watershed related components – soil conservation, agriculture, animal husbandry, forestry etc. While each of them may be capable of executing the individually assigned tasks, what is principally absent is a commonality of objective and the capacity to converge their resources & efforts and comprehension to appreciate the organic inter-linkages. Many a time, they also fail to recognize the critical importance of community participation. The execution approach is quantitative targeting and that too in isolation. For successful translation of the watershed principles, the PIA needs to be oriented and trained in community participation, coordinated work, team spirit, mobilisation & institution building etc. apart from respective domain knowledge. Deployment of appropriate ICT tools in management and evaluation of the changing values of key parameters (eg. vegetative cover, water level etc.) is necessary and useful in watershed management.

1.9. Government Schemes

I. PMKSY – Watershed Development Component

Integrated Watershed Management Programme (IWMP) was amalgamated as the Watershed Development Component (WDC) of the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) in 2015-16. WDC-PMKSY is principally for development of rainfed portions of net cultivated area and culturable wastelands. The activities being undertaken *inter alia* include ridge area treatment, drainage line treatment, soil and moisture conservation, rain water harvesting, nursery raising, afforestation, horticulture, pasture development, livelihoods for asset less persons, etc.

About 8,214 number of watershed development projects were sanctioned during the period of 2009-10 to 2014-15 in 28 states (except Goa) involving an area of about 39.07 million ha. The central share is Rs. 33,642. 24 crore, the total project cost being Rs. 50,739. 58 crore (sharing pattern being 60:40 for general states; and 90:10 in case of north eastern & Himalayan states).

A geo-spatial portal SRISHTI has been in operation since 2015 with assistance of National Remote Sensing Centre (NRSC) for monitoring. It has been extended to all states (except Goa) in 2016. Geo-coded and time-stamped photographs on near real-time basis are uploaded on SRISHTI portal using a mobile application DRISHTI specifically developed for the purpose.

Shortcomings as evidenced are appropriately taken up for resolution on a continuing basis by the project implementers. Public Financial Management System (PFMS) is being implemented w.e.f. 2015-16. As many as 26 out of 28 states have adopted the PFMS platform [(Andhra Pradesh and Telangana use Electronic Fund Management System (EFMS) as adopted by the two state Governments)]. The Chairmen of SLNAs of all States (except Goa) were requested on 23rd May 2017 that (a) cent per cent transfer of funds from SLNA to Watershed Cell cum Data Centre (WCDC), WCDC to Project Implementation Agency (PIA) and Watershed Committees (WC) may be ensured through PFMS; and (b) payment for goods, services, labour, etc. at all levels i.e SLNA, WCDC, PIA and WC may be made through PFMS wherever feasible. They were also requested that digital modes of transactions may be proactively adopted wherever feasible, and that the public are concurrently made aware, encouraged and motivated for adopting digital transactions.

With the adoption of the strategies of (i) optimal utilization of available resources, (ii) convergence; and (iii) prioritization, besides accountability and real-time monitoring, administrative reports of completion of projects are now being continuously received. This is a great improvement.

Around 1140 projects in 13 states have been reported to be completed after 1st April 2017. As a systemic improvement, a protocol on formal completion and closure of WDC-PMKSY projects has been formulated by the Department of Land Resources in consultation with Ministry of Water Resources, River Development & Ganga Rejuvenation and NITI Aayog. The protocol inter alia envisages to ensure (i) the due completion of unfinished works (if any), (ii) maintenance, (iii) security and (iv) sustainability of the watershed development projects. It also includes (v) an apt, quick and low-cost / cost-effective end-line evaluation of the project or a group of projects within the approved cost norm for M&E component. The learnings from such evaluations will be of immediate use for qualitative improvements in case of the remaining ongoing projects (as well as in future project implementation). Before the projects are formally treated as closed by the Department of Land Resources, the completion and closure protocol has to be duly adopted by the states in respect of the projects administratively reported to have been completed.

II. World Bank Assisted Neeranchal National Watershed Management Project (WB – NWMP) "Neeranchal"

Neeranchal National Watershed Management Project (Neeranchal), sanctioned in 2015-16, is meant to provide support to WDC - PMKSY through technical assistance to improve incremental conservation outcomes and agricultural yields for communities in selected sites, and adoption of more effective processes and technologies in participating states. The project is being implemented with focused effort in 18 selected districts in 9 States of Andhra Pradesh, Chhattisgarh, Gujarat, Jharkhand, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, and Telangana. The experiences gained and innovations developed will feed into the implementation of the WDC-PMKSY in all the 28 states (except Goa) of the country where watershed development projects are under implementation.

The Neeranchal project will also strengthen key national and state level institutions that currently implement WDC - PMKSY including the Department of Land Resources at the National level, the State Level Nodal Agencies and field staff for watershed development at the State / ground level. National level partner agencies and various state level institutions will also benefit from improved coordination of research and more effective approaches for technology transfer to communities and farmers.

The total outlay of the project is Rs 2,142.3 crore ($ 357 million) out of which 50 per cent amount will be provided as long term loan by the World Bank. National Institute of Hydrology (NIH) has been engaged as an Implementing Partner through Memorandum of Understanding (MoU) entered into on 10th November 2016 for providing a Decision Support System for Hydrology to the States and developing the capacity of ground level staff for its implementation. Rs. 1.70 crore has been released to NIH so far.

In order to ensure, (a) synergy, (b) coordination, (c) information flow between WDC-PMKSY and Neeranchal, and having regard to the (limited) availability of officers, the same set of officers have been assigned the responsibilities of WDC-PMKSY and Neeranchal. The Project Director of Neeranchal and the Divisional Head In-charge (Joint Secretary level) of WDC-PMKSY are one and the same officer.

Official / Institutional Support to Project Implementation Unit (PIU) of Neeranchal has been systematized (O.M.s dated 17th May 2017 and 23rd May 2017). The Forest Research Institute (FRI) has been engaged as Capacity Building Support Agency (CBSA) through an MoU entered on 27th December 2017 for providing training and capacity building in the States (where the actual implementation takes place). Rs. 0.20 crore has been released to FRI so far. NIH [for hydrology (which is one critical fundamental for watershed development)] and FRI [(for training and capacity building (which is another critical fundament for watershed development)] are both qualitative professional government organizations.

Some of the advantages of having a government organization are, that the latter will be governed by government rules and regulations; will be comparatively more accountable; meetings / dialogue with such organization will be comparatively more convenient the arrangement with a government organization are comparatively more readily feasible (directly through an MoU); and dynamic changes as appropriate in accordance with the changing needs, if any, will be relatively more readily feasible. In addition, such government organization will become the natural repository of information and knowledge gathered under the Neeranchal Project, and the same would sustain and be available for productive use of watershed development implementers as well as students and researchers in this field. Both the government organization and the implementers and students and researchers of the country will continue to benefit even after completion of the Project.

1.10. Annotation

In agricultural systems, common practices include the use of buffer strips, grassed waterways, the re-establishment of wetlands, and forms of sustainable agriculture practices such as conservation tillage, crop rotation and intercropping. After certain practices are installed, it is important to continuously monitor these systems to ensure that they are working properly in terms of improving environmental quality.

In urban settings, managing areas to prevent soil loss and control storm water flow are a few of the areas that receive attention. A few practices that are used to manage storm water before it reaches a channel are retention ponds, filtering systems and wetlands.

It is important that storm water is given an opportunity to infiltrate, so that the soil and vegetation can act as a "filter" before the water reaches nearby streams or lakes. In the case of soil erosion prevention, a few common practices include the use of silt fences, landscape fabric with grass seed and hydro-seeding. The main objective in all cases is to slow water movement to prevent soil transport.

Several anthropogenic activities accelerate slope instability which needs to be prevented and efforts should be made to protect the watershed by preventing overgrazing, terracing and contour farming to check run-off and erosion.

Key Extracts

- Water for food production is becoming an increasingly scarce resource, and the situation is getting further aggravated by climate change.
- The rainfed areas are the hot spots of poverty, malnutrition, food insecurity, prone to severe land degradation, water security and poor social and institutional infrastructure.
- Watershed development programmes are considered as an effective tool for addressing many of these problems in fragile soil areas, in intensively cultivated lands and marginal rain-fed areas.

Chapter 2
Rainfed Agriculture: challenges and strategies

Rainfed areas are highly diverse, ranging from resource-rich areas with good agricultural potential to resource-poor areas with comparatively restricted potential. A new macro policy that articulates for decentralised, location-specific, integrated approaches in rainfed areas is necessary for agriculture to be inclusive, climate-resilient & sustainable, and to provide the needed food and nutritional security.

2.1. Introduction

Currently, the rainfed agriculture, which is totally rain dependent, accounts for 55 per cent of the net sown area of the country. Rainfed agriculture is crucial to country's economy and food security since it contributes to about 40 per cent of the total foodgrain production (85, 83, 70 and 65 per cent of nutri-cereals, pulses, oilseeds and cotton, respectively); supports two-thirds of livestock and 40 per cent of human population; further also influences livelihoods of 80 per cent of small and marginal farmers and is most vulnerable to monsoon failures. Even if full irrigation potential gets to be created, still 40 per cent of net cultivated area will remain as rainfed agriculture which would continue to be a major foodgrain production domain.

The Green Revolution in mid-sixties, though a boon to Indian agriculture at the macro level, it ushered in an era of wide disparity between productivity of irrigated and rainfed agriculture. It largely by-passed the rainfed agriculture including the eastern region of the country. Several development programmes were initiated for improving rainfed farming. The *"Everything Everywhere"* approach of taking up all major interventions uniformly across all regions of the country has not paid much dividend. The developmental approach in rainfed areas did not fully capture aspects like livelihood, soil resources, reliability of irrigation, socio-economic profile, infrastructure, etc. neglecting region-specific interventions befitting to the natural resource endowment, social capital, infrastructure and economic condition (NRAA, 2012). Rainfed agriculture is complex, diverse and risk prone. It is characterized by low levels of productivity and input usage coupled with vagaries of monsoon emanating from climate change, resulting in wide variation and instability in yields. In view of the growing demand for foodgrains in the country, there is a need to develop and enhance the productivity of rainfed areas. If managed properly, these areas have tremendous potential to contribute a larger share in food production and faster agricultural growth compared to irrigated areas which have reached a plateau. The state of rainfed agriculture is precarious and the problems associated with it are multifarious. To name the more striking ones: low cropping intensity, high cost of cultivation, poor adoption of modern technology, uncertainty in output, low productivity, increasing number of suicides among farmers, lack of institutional credit, inadequate public investment and high incidence of rural poverty (Singh et al., 2010).

The major challenge of rainfed agriculture in the decades to come will be sustaining the livelihoods of small and marginal farmers who will still depend on agriculture despite increased climate variability and shrinking land holdings.

2.2. Managing Risks: Key Issues

The rainfed agriculture is totally dependent on south-west monsoon and thus, is synonymous with risk due to erratic monsoon. A decrease of one standard deviation from the mean annual rainfall often leads to a complete loss of the crop. Dry spells of 2 to 4 weeks during critical crop growing stages cause partial or complete crop failure. Climate change and climate variability impacts Indian agriculture in general and more pronounced by the rainfed agriculture. The evident climate shifts in rainfed areas will have larger implications for crop planning, water resources assessment and prioritizing drought proofing programmes. Rainfed crops are likely to be worst hit by climate change because of the limited options for coping with variability of rainfall and temperature. The projected impacts are likely to further aggravate yield fluctuations of many crops with negative influence on food security and prices. Compound growth rates and instability index of major rainfed crops reveal that all the major crops registered negative growth in spite of the technologies such as new variety, fertilizers etc. The yield could not be increased significantly due to vagaries in monsoon and temperature, despite intervention through various governmental schemes.

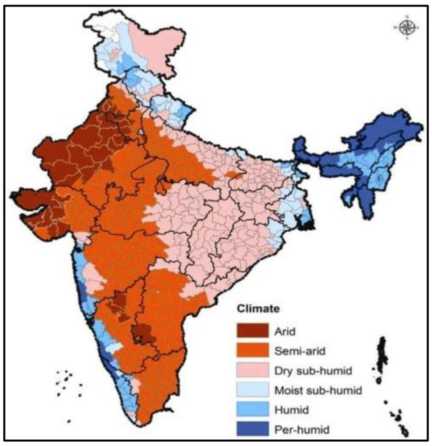


Figure 2.1 Climatic classification at district level. *Source: Raju et al. 2013*

Climatic risks like droughts and floods, and poor water and nutrient retention capacity of soil and low soil organic matter (SOM) impact negatively the rainfed agriculture. Risk is also to be addressed in terms of building resilience of crops, soils and farmers. Resilience to climate change will depend on increasing agricultural productivity with available water resources; refining technologies and timely deployment of affordable strategies to accomplish potential levels of arable land and water productivity. In this context, it seems rational for overall agricultural policy as well as the research system to prioritize issues related to resilience to climate risks, and strengthen the capacity of natural resources to overcome various forms of climate stress, as a critical requirement to achieve food security.

2.2.1. Bridging yield gaps

Although the average per hectare productivity levels have increased from 0.6 tonnes in 1980s to 1.2 tonnes at present in rainfed areas, large gaps still remain in several crops and regions between yields obtained at research stations and on farmers' fields. In several disadvantaged areas, the yield gaps will continue to remain large unless tailor-made package of practices are developed and farmers are encouraged to adopt the same. While evolving strategies for bridging yield gaps, due attention must be given to regional imbalances in terms of natural resources and technology intake capacity of farmers. For yield maximization, selecting genotypes with wide adaptability and resilience to climate variability remains a challenge.

The projected area, production and yield of cereals under various production systems in India for 2030 and 2050 indicate, that while irrigated systems can contribute an additional yield of 15 per cent, the rainfed systems could remain the same. Thus, there would be need for a strategic mix of better technology adoption, institutional innovations and incentives system to enhance productivity of rainfed cereals.

Table 2.1 Projected area, yield and production of cereals under different production systems

Cereals	2030	2050
Rainfed area (m ha)	40	36
Rainfed yield (t/ha)	1.8	2.0
Rainfed production (mt)	73	72
Irrigated area (m ha)	57	62
Irrigated yield (t/ha)	4.3	4.6
Irrigated production (mt)	248	285
Total area (mha)	97	98
Total yield (t/ha)	3.3	3.7
Total production (mt)	321	357

Source: Observations, projections and impacts – India 2011 UK Met office report

2.2.2. Water risks

The basic resource which determines the success of rainfed agriculture is water availability. Inspite of large irrigation potential created (108 million ha), the gaps between gross sown and gross irrigated area and net sown and net irrigated area are about 105 million ha and 78 million ha, respectively. As the demand for water from non-farm sectors increases and availability to agriculture declines, the conflicts between upstream and downstream users may increase over time. A fallout of such process is the possible conversion of existing productive irrigated lands to rainfed lands.

It is estimated that even after achieving full irrigation potential, nearly 40 per cent of the total cultivated area of the country will still remain rainfed. An important challenge facing the irrigation sector in India is the growing gap between Irrigation Potential Created (IPC) and Irrigation Potential Utilized (IPU). The estimated gap is an alarming 23 million ha. The overall irrigation efficiency of the major and medium irrigation projects is estimated to be around 38 per cent.

The efficiency of surface irrigation system can be improved from about 35-40 per cent to around 50-60 per cent and that of groundwater from about 65-70 per cent to 72-75 per cent (Planning Commission, 2009). The National Water Mission, institutionalized under the National Action Plan for Climate Change, has targeted to improve the efficiency of water use by at least 20 per cent. At present in India, blue and green water availability is above the 1,300 m^3/capita/year threshold. However, with climate change, blue-green water availability is estimated to decrease to less than 1,300 m^3/capita/year implying that by 2050 all of India could be exposed to water stress.

2.2.3. Soil health risks

The major soil constraints that are limiting productivity of rainfed crops are shallow depth, low plant available water capacity(PAWC), sub-soil hard pans, very low sub-soil saturated hydraulic conductivity, imperfect soil/land drainage, sub-soil gravelliness, calcareousness, low soil organic carbon, multiple nutrient deficiencies etc. The magnitude of soil loss ranges from 5 to 150 t/ha/year depending on soil type, land use and slope.

The multiple nutrient deficiencies in soils of rainfed field and horticulture crops are estimated to be 89 per cent for N; 80 per cent for P; 50 per cent for K; 41 per cent for S; 48 per cent for Zn; 33 per cent for B; 12 per cent for Fe; 13 per cent for Mo and 5 per cent for Mn. Soil degradation comes in several forms, including erosion by wind or water, and chemical deterioration such as loss of nutrients or salinization. The soil organic carbon is 5 g/kg in soils in rainfed areas whereas the desired level is 11 g/kg. A severe depletion of soil organic carbon (SOC) stock, to below the threshold level in the root zone, has adverse effects on bio-mass production, root bio-mass, residues re-cycling and agronomic yields because of reduction in the use efficiency of added inputs. Although about 80 mt of crop residues are produced annually in rainfed areas, the recycling is not done due to competitive uses and burning.

2.2.4. Low and skewed farm mechanization

The level of farm mechanization in rainfed areas is very low due to small and marginal holdings, resource poor farmers etc. Whatever little farm mechanization is practised, it is mostly at land preparation stage and is extremely low at intercultural, weed management and harvest stages. The average farm power availability needs to be increased to a minimum of 2.5 kW/ha with 70-80 tractors per 1000 ha to assure timeliness and quality in field operations.

2.2.5. Market risks

Access to markets is an essential requirement for the small and marginal resource poor farmers in rural areas. Markets in India, particularly in rainfed regions are underdeveloped and farmers are exposed to high price risk. Small and marginal farmers now constitute over 86 per cent of farming households in India. They have only very small quantities of marketable surplus. The major problems in linking farmers to markets in rainfed areas include: lack of quality output and absence of grading before marketing, inadequate storage and warehousing facilities, transport facilities and market intelligence, lack of proper facilities for farmers in the market yards, cash cutting while payments, improper weighing etc., distress sales due to debt obligation, and more critically absence of an environment for aggregation / assembly of the small lots. In the absence of sound marketing facilities, the farmers have to depend upon local intermediaries for the disposal of their farm produce which results in produce being sold at low or sub-optimal price, at minimal or zero profit. This necessitates strong support systems for regulated markets including e-marketing.

2.2.6. Lack of processing and value addition facilities

Heavy post-harvest losses at around 25-30 per cent for fruits and vegetables are common. Some of the current weaknesses in the system are lack of grading, standardisation and scientific packaging at the post-harvest management stage. Direct market connectivity through efficient post-harvest logistics, effective marketing network, agro-processing and value addition where possible is the most effective solution to optimise on value capture and to minimise on resource use wastage.

In rainfed areas, millets, pulses & oilseeds are common field crops. All these, and millets (nutri-cereals) in particular need processing facilities at farm gate / village level. These are not in adequate numbers.

2.2.7. Poor policy support

The policy makers have generally perceived rainfed areas as drought prone, low in productivity, high in risk, and backward; and in result have received limited attention. An estimate by the Centre for Budget and Governance Accountability suggests that during 1997-98 and 2011-12 of the total expenditure on agricultural subsidies of about Rs. 11.5 lakh crore, only 1 per cent was on rainfed agriculture. The rest was on intensive agriculture – divided into price support/food (38 per cent), fertilizer (37 per cent), irrigation (21 per cent) and electricity (3 per cent) (Mishra et al., 2013). This is unfair considering, that rainfed areas are larger than irrigated areas and farmers are poorer in rainfed regions. Given the right support of R and D policy incentive, rainfed regions can do much better, and it is the need of the hour.

2.3. Environmental footprints of changing demand profile

With rising incomes, the demand for high energy food (milk, meat, eggs and oils) will increase. For instance, milk and meat demands in India by 2050 are estimated to be around 110 and 18.3 mt respectively. Such production levels could be attained by intensive animal rearing systems like semi- and stall-feeding; placing more demand for fodder, feed and water; and breed improvement. The projected domestic demand for different crop groups shows that rice and wheat may be surplus whereas other cereals will be in acute shortage (CRIDA Vision, 2015).

The deficit would be primarily for oilseeds, fruits, vegetables and pulses. Hence, the challenge would be to enhance productivity levels of these crops by promoting breeding programs and dryland horticulture. Further, as rice and wheat are going to be surplus, we need to follow a two-pronged strategy i.e. to increase their productivity by bridging the yield gaps and shifting some of the area under these crops to other cereals and vegetables through integrated farming systems approach which optimize the use of natural resources. Currently, there is an imbalance between natural resources endowment and cropping patterns in the country. It is an irony that areas with less rainfall are net exporters of agricultural produce to areas with sufficient rainfall and untapped groundwater potential (CRIDA Vision, 2015).

2.4. Specific Strategies for Sustainable Agriculture in Rainfed Areas

2.4.1. Enhancing and stabilising productivity

The cropping pattern in a rainfed areas is largely driven by management (accumulated knowledge), monsoon (south-west), and often market influence. Traditionally, mixed or inter-cropping were dominating in core rained areas which provide risk resilience during aberrant weather condition in crop growing season. Recently, the cropping pattern in rainfed areas are witnessing shifts to mono-cropping, particularly to rainfed cotton replacing pulses, millets, oilseeds crops. Currently, there is an imbalance between natural resources endowment and cropping patterns in rainfed areas. This calls for concerted efforts in efficient crop zoning/crop colonies/crop alignment matching natural resources, majorly rainfall and soil resources.

Efficient crop zones have similar geographic setting in terms of soils, landforms, rainfall, temperature, length of growing period, irrigation potentials, suitable for a specific crops and cropping sequences and have the potentiality to response similarly for similar kind of management practices. Potential crop zoning involves development of soil-site characterization, bio-physical suitability evaluation and linking of bio-physical suitable maps to the relative spread and productivity of reference crops and cropping sequences. Methodology for delineating potential crop zone is described hereunder (Fig. 2.2. Ramamurthy et al. 2016)

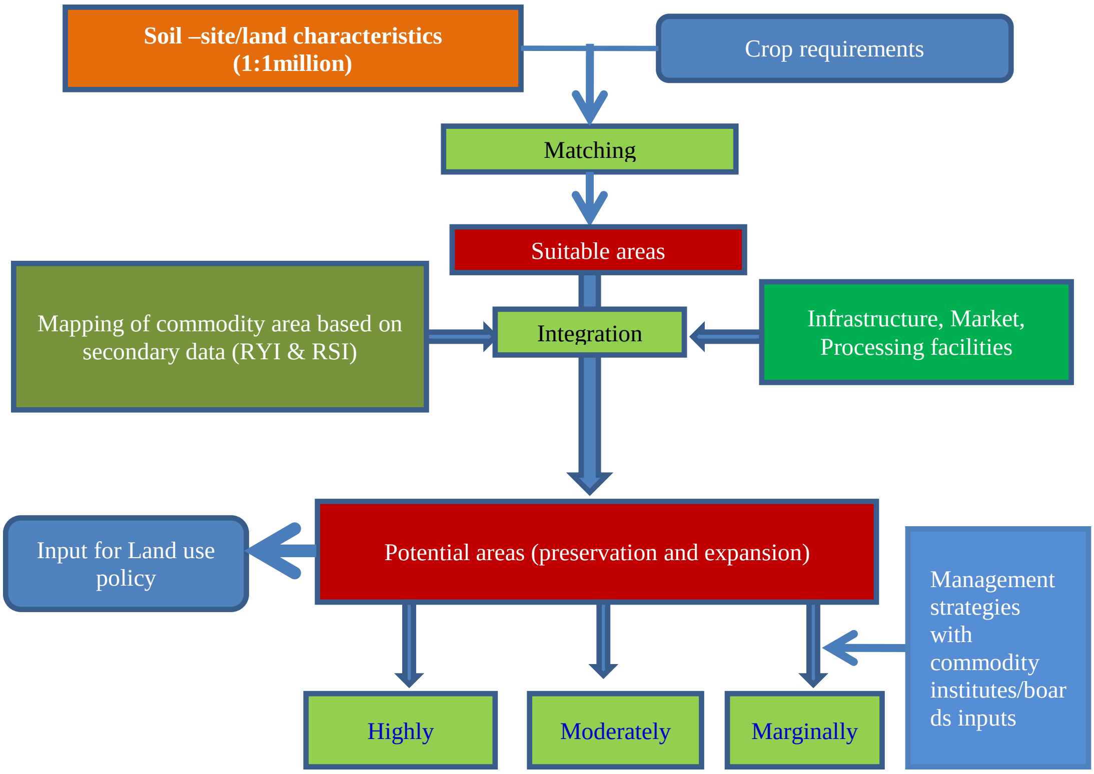


Figure 2.2 Methodology for delineation of Potential Crop Zones (Ramamurthy *et al.* 2016)

2.4.2. Commodity crop specific strategies

Pulses are grown across the country with the major share coming from Madhya Pradesh (21 per cent), Rajasthan (16 per cent), Maharashtra (15 per cent), Karnataka & Uttar Pradesh (10 per cent each) and Andhra Pradesh and Telangana (8 per cent together), which together account for 80 per cent of total area under pulses. The short fall in pulse production has been attributed to many factors major ones related to natural resource management could be inter-annual and in-season drought, floods and extreme events like excess rainfall events, hailstorm etc., poor soil quality with multiple nutrient deficiencies, unabated land degradation of various kinds and extent. These challenges get exacerbated since pulses in the country are generally grown on marginal lands and as rainfed crops.

The introduction of many improved varieties of pulse crops in core pockets could increase pulse production. However, the syndrome of less than 1 ton per ha productivity of majority of pulse crops in rainfed areas is due to poor management of natural resources viz. land, soil and water. The research efforts in AICRPDA network identified agro-climatic-zone wise and soil zone wise risk resilient intercropping systems with pulse crop as one of the component.

Table 2.2 Agro climatic zone and soil zone wise risk resilient intercropping systems

Soil zone/ Agro climatic zone/State	Inter-cropping system
Vertisols and Vertic Inceptisols	
Malwa plateau, Madhya Pradesh	Soybean + pigeon pea (4:2)
	Sorghum + pigeon pea (2:2)
Western Vidharbha, Maharashtra	Cotton + greengram (1:1)
Southern Rajasthan	Maize + blackgram (2:2)
Northern Dry zone, Karnataka	Pearl millet + castorbean (3:1)
	Pearl millet + pigeonpea (4:2)
Northern Saurashtra, Gujarat	Groundnut + castorbean (3:1)
	Groundnut + pigeonpea (3:1)
Southern Tamil Nadu	Cotton + blackgram/ greengram (2:1)
Inceptisols and related soil zone	
Western plateau, Jharkhand	Pigeon pea + rice (2:3)
	Maize + cowpea (2:2)
Alfisols/ Oxisols zone	
Eastern Ghat zone, Odisha	Maize + pigeon pea (2:2)
	Fingermillet + pigeon pea (4:2)
Alfisols zone	
Southern dry zone, Karnataka	Groundnut + pigeon pea (8:2)
	Fingermillet + pigeon pea (10:2)
Southern zone, Telangana	Sorghum + pigeon pea (2:1)
Scarcity zone, Andhra Pradesh	Groundnut + pigeon pea (7:1)
Aridisols zone	
Northern zone, Gujarat	Castor bean cowpea (1:2)
	Pearl millet + clusterbean (2:1)

Source: AICRPDA Annual Reports 2003-15

2.4.3. More crop and income per drop of water

A feasible strategy for realizing the potential of rainfed agriculture in rainfed districts is to harvest a small portion of available surplus runoff, which is very site/agro-ecology specific and has to be quantified for storage in water harvesting structures like farm pond and utilized for supplemental/protective irrigation during critical crop growth stages.

About 27.5 million hectares (Mha) of potential rainfed area, which not only accounts for most of the rainfed production but also generates sufficient run-off (114 Bm^3) for water harvesting, and can be utilised to increase rainfed production by 50 per cent over this area with application of one supplemental irrigation (Sharma et al. 2010) along with adoption of rained crop-specific crop and soil management practices.

Strategies for increasing irrigated potential/area in rainfed areas are:

- Harvesting available water resources for stable irrigation.
- The groundwater potential in eastern region of the country is yet to be utilised rationally.
- Flood water management in north-eastern region
- Implementation & popularization of agro-ecology specific (soil & rainfall) in-*situ* moisture conservation practices.
- Mapping potential sites for rainwater harvesting in farm ponds.
- Popularization of farm pond technology package (selection of ideal site, digging, harvesting, lining, minimizing evaporation losses, lifting pump, micro-irrigation system)including efficient utilization of stored water for higher water productivity (More Crop and Income per Drop of Water).
- Desilting tanks to increase stored volume of water for irrigation of crops & groundwater stabilization.
- Adoption of water saving technologies viz., drip & sprinkler irrigation in commercial field & horticultural crops.
- Augmenting & popularization of use of treated waste-waters for irrigation.
- Popularization of recommended tank silt application in light textured soils.

2.4.4. Soil fertility management

Implementation of appropriate land use and management practices which can maintain and enhance both carbon storage and other ecosystem services is an important strategy for climate moderation and also for enhancing the provisioning services from the rainfed systems. Crop residues are a principal source of carbon which constitute about 40 per cent of the total biomass on dry weight basis. The role of crop residues on carbon sequestration in soils would be an added advantage in relation to climate change and mitigation of GHG emission. Generally, farmers burn crop residues like stalks of pigeonpea and cotton without recycling them. Therefore, shredding of crop residues should be mechanized.

2.4.5. Quality seed production

Efficacy of all other agricultural inputs, such as fertilizers, pesticides and irrigation, etc., as well as the impact of agro-ecological conditions, is largely determined by the quality of the seed used. The estimated contribution of seeds in the productivity is considered to be 20 to 25 per cent. In this regard, emphasis is needed on:

- Research and development for improved cultivars in major rainfed crops viz., rice, nutri-cereals, pulses, oilseeds, green manure and fodder crops.
- Production and timely supply of adequate breeder seed for further multiplication of Foundation and certified seeds.

2.4.6. Diversifying within farm

Evolving Integrating Farming Systems (IFSs) models that are suited to rainfed areas is of critical importance. The focus can be on identifying and upgrading traditional rained farming systems that enhance resource use efficiency and livelihoods. Suggested strategies for strengthening traditional rained farming systems are given in Table 2.3. These include: promotion of proven agro-ecology specific alternate land use systems/ agro-forestry systems based on land capability in private and public for risk resilience and staggered income, bio-mass production, soil carbon sequestration, promotion of pasture, silvi-pasture systems, fodder trees, and multiple tree based systems in non-arable land, particularly in village common lands.

Table 2.3 Suggested strategies for strengthening traditional rained farming systems

Rainfall zone (mean annual rainfall)	Strengthening predominant traditional rained farming systems	Agro-ecology specific components along with efficient *in situ* and *ex situ* rainwater management practices
< 500 mm	Livestock-crop based	Small ruminants, nutritious cereals/millets
500-750 mm/	Crop-horticulture-livestock based	Small/large ruminants, predominant rained crops and dryland horticulture
750-1000 mm	Crop-horticulture-livestock-poultry based	Predominant rained crops, dryland horticulture, agri-hortisystems, rainfed vegetable crops, small/large ruminants, improved breeds of poultry
> 1000 mm	Multiple enterprise based on multiple water use	Predominant rained crops, lowland rice with water saving technologies, dryland horticulture, vegetable crops, other high value crops, agri-hortisystems, small/large ruminants, improved breeds of poultry, fish and other income generating enterprises like seed production, apiary, mushroom cultivation etc.

The action points for enhancing productivity and income through various components of rained farming systems viz. dryland horticulture, animal husbandry, poultry etc. are briefly presented.

2.4.7. Dryland horticulture

Dryland horticulture enhances adaptive capacity and provides risk resilience to rainfed farmers in the backdrop of climate change/variability and failure of annual crops due to weather aberrations. However, many challenges being encountered in dryland horticulture are:

production of high yielding, disease free planting material of identified fruit varieties, commercialization and packaging of high density planting system including canopy management techniques in potential fruit crops, creation of water harvesting structures linking with water saving technologies suitable for horticulture crops in rainfed areas, promotion of mechanization to bring efficiency in rained production systems etc. The action points for enhanced and stabilized productivity from dryland horticulture are:

- Identification and promotion of dryland horticulture in the prioritized rainfed districts with some assured source of irrigation in the initial stages of establishment of orchards.
- Special emphasis on establishment of mother blocks/root stock blocks with hi-tech nurseries and tissue culture units including accreditation of nurseries.
- Area expansion linked to availability of quality planting material.
- Cultivation of vegetables under rainfed condition or with supplemental irrigation.
- Packaging high density (> 1000 plants/ha) technology in potential fruit crop regions in prioritized rainfed districts with suitable varieties, raised bed cultivation, canopy management, irrigation and fertigation schedules, harvesting and post-harvest protocols for enhanced yield of export quality and higher net profits.
- Tree canopy management right from establishment stage for regular and uniform flowering, ease in plant protection, harvesting etc.
- Integrated approach, adoption of drip irrigation and fertigation technology involving drip systems, fertigation equipment, plastic mulching, automation, use of sensors etc.
- Capacity building through skill, training & demonstration of improved technologies.

2.4.8. Alternate land use system

Agro-forestry systems in rainfed areas produce food, fuel, fodder, timber, manures and fibre, contributing to food, nutritional and environmental security; sustenance of livelihoods, alleviation of poverty and promotion of productive and climate resilient cropping and farming systems. This farming system also has the potential to enhance eco-system services through carbon storage, prevention of deforestation, bio-diversity conservation, and soil amelioration. In addition, when strategically applied on a large scale, with appropriate mix of species, agro-forestry enables agricultural land to withstand extreme weather events, such as floods and droughts, and climate change. Integration of perennials into the arable systems not only provides additional income to the farmers but also reduces probable risk during the years of low rainfall and weather extreme events (unseasonal high intense rainfall, cold wave, heat wave, drought and cyclones etc). Tree/perennial systems improve soil fertility and contribute towards amelioration of salt-affected soils and diversify production for increased social, economic and environmental benefits. Trees in agricultural landscape protect and stabilize ecosystems, provide material to meet basic requirements of rural population such as fuel, fodder to animals during drought and other extreme events such as floods and generate additional employment. Hence, integrating trees into agricultural landscapes is an approach for sustainable intensification of arable systems and contributes towards enhancing productivity in unit time and area with multifarious benefits, thus enhancing the adaptive capacity of farmers to climate risks.

In arid regions, ber based systems were found promising and the extent of improvement in profitability in comparison to arable cropping was reported upto 105 per cent. In addition, ber leaves make excellent fodder and the prunings are excellent fuel wood. Fruit trees such as *custard apple, phalsa, karonda and jamun* are found suitable for areas where rainfall is less than 500 mm. On the other hand, fruit crops such as *mango, lime, lemon, guava, pomegranate, aonla, jamun, wood apple and tamarind* are recommended for areas where the rainfall is more than 600 mm. *Prosopis cineraria* based systems are widely practised in much of Rajasthan receiving rainfall less than 600 mm which is reported to increase yields under its vicinity and also provide valuable fodder.

2.4.9. Animal husbandry

Livestock, particularly in rainfed areas is an integral part of agriculture and rural economy. The livelihood and nutritional security provided by livestock rearing is enormous. Further, the net output from per unit of investment is comparatively high in livestock farming even under adverse seasonal conditions like severe droughts. While the farmers' income has been growing at 3.5 per cent annually in India, income from livestock is growing at about 14.5 per cent. Therefore, in order to double the income of farmers, it is important to focus on the allied enterprises viz., dairy, sheep, poultry and fisheries sector particularly in case of small and marginal farmers.

These sectors have the advantage of range of products, domain expertise, large market and infrastructure in the country. Unlike crops, there is no price volatility in case of milk, poultry, and sheep & fish meat. Therefore, there is advantage in mobilizing small and marginal farmers towards allied enterprises. Cooperatives have played a vital role in the development of the dairy sector. Milk cooperatives need to be spread in rainfed areas with value addition. Dairy, sheep and poultry farming can be made more attractive and profitable through commercialization. Financing by commercial banks can be encouraged.

2.4.10. Protected agriculture

Production of crops under protected environment viz., greenhouses, shade nets, shallow & walking tunnels etc., is picking up in peri-urban areas, ensuring a constant, year-round supply of high-quality vegetables and flowers. This technology embedded with precision farming principles of micro irrigation and fertigation is proving to be an attractive agri-enterprise.
The following are suggested for promotion of protected agriculture in rained areas:

- Provision of regular un-interrupted power supply to maintain optimal growing conditions within protected structures.
- Ensuring supply of quality seeds/nursery/other planting material suitable for poly-house cultivation of crops.

- Self-help groups with scientific support should be promoted for multiplication of quality planting material for protected cultivation.
- Support and promote protected cultivation by adopting cluster approach, especially in peri-urban areas.
- Development of input hubs for easy accessibility.
- All the protected cultivation clusters should be mandatorily clubbed with rain water harvesting infrastructure and facilities.
- Large-scale motivation and training of educated unemployed youth in the field of protected cultivation.
- Handholding by SAUs, KVKs and ICAR institutions.

2.4.11. Fodder production

Cropped area under fodder production is about 11 m ha (6.25 per cent). By 2020, Indian livestock need 526 million tonnes (mt) of dry matter, 56 mt of concentrate feed and 855 mt of green fodder (as fed) for optimum productivity (Dikshit and Birthal 2010). Presently, there is a net deficit of 61.1 per cent green fodder, 21.9 per cent dry crop residues and 64 per cent concentrate feeds in the country. About half of the annual fodder requirement is met from the cultivated fodder and crop residues. About 91 per cent of households depend on open grazing for an average of 35 per cent of the total forage requirement of the animal. 82 per cent of large farmers also depend on common lands for open grazing.

Potentially productive common property resources (CPRs) are very less and 40 per cent of are either not productive or are producing well below the average due to over grazing and lack of protection measures. The recent National Livestock Policy aims at increasing livestock productivity and production in a sustainable manner while protecting the environment, preserving animal bio-diversity, ensuring bio-security and farmers' livelihood. Some of the strategies for development of efficient pasture and or fodder production systems in rainfed areas include:

- *Fodder production from arable lands:* Each farmer should at least allocate 10 per cent of his land for fodder production. Further, on the bunds of all soil and water conservation structures, encourage seeding of fodder varieties like *Stylo* and *Cencherus*.
- *Integrated fodder production systems:* Integrate of rearing of ruminants with trees in the form of silvi-pastoral, agri-silvi-pastoral, and horti-pastoral systems. Fodder crops like *Stylo hamata* and *Cenchrus ciliaris* can be sown in the inter-spaces between the tree rows for fodder production.
- *Tank beds- Common Pool Resources for fodder production:* Due to silt deposition, tank beds are fertile and retain adequate moisture in the soil profile for cultivation of short season fodder crops like sorghum and maize fodder.
- *Intensive rainfed fodder production systems:* Growing of two or more annual fodder crops as sole crops in mixed stands of legume (*Stylo* or cow pea or hedge Lucerne etc.) and cereal fodder crops like sorghum, ragi in rainy season followed by berseem or

Lucerne etc. in *rabi* season in order to increase nutritious forage production round the year.

- *Perennial non-conventional fodder production systems:* Perennial deep rooted top feed fodder trees and bushes such as *Prosopis cineraria, Hardwickia binata, Leucaena leucocephala, Acacia nilotica* trees and modified plants of cactus are highly drought tolerant and produce top fodder.
- *Fodder production systems in homesteads: Azolla*, a blue green algae which has more than 25 per cent of crude protein can be grown in pits at backyards depending on the number of milch animals owned by the farmer. It is more nutritious than leguminous fodder crops like lucerne, cowpea, berseem etc. and can be fed to cattle, buffalo, sheep, goat and also poultry after mixing with concentrate mixture at the ratio of 1:1.
- *Fodder production as contingency plan:* During early season drought, short to medium duration cultivated fodder crops like sorghum (Pusa Chari Hybrid-106 (HC-106), CSH 14, CSH 23 (SPH-1290)etc.) which are ready for cutting by 50-60 days and can be sown immediately after rains under rainfed conditions in arable lands during *kharif* season.

2.4.12. Food processing & value addition

The rural based low cost small scale agro-industries in rainfed areas are required for process able surpluses. These would not only help in recovering some of the post- harvest losses that occurs at farm level but would also generate much needed rural employment opportunities considerably.

Hence, emphasis is required on creation of multi-purpose low cost rural based agro-processing complexes/parks within a given time frame. For this, the Farmers Self Help Groups (SHG)/Cooperatives/Farmer Producer Companies be established with provisions of needed credit and policy incentives. Some of the action points for promotion of food processing and value addition in rainfed areas are:

- Establishing processing and value addition units at strategic places in the rural areas/production areas for pulses, millets, fruits, vegetables, dairy, fisheries and poultry in public private-partnership (PPP) mode.
- Establishing food quality testing and phyto-sanitary laboratories.
- Helping farmers in marketing of their processed products (forward linkages).
- Skill development, particularly farmwomen in primary and secondary processing.
- Training in grading and packaging of horticultural crops should be a priority.

2.4.13. Farm mechanization

Empirical evidence confirms that there is a strong correlation between yield increases and the rate of farm power employed. Thus, states in India with a greater availability of farm power show higher productivity as compared to others. Mechanization is an essential input not only for crop production, but it also has a crucial role to play along the entire value chain. By mechanizing the whole process of agricultural crop value addition from planting to marketing, higher value outputs can be produced, rural employment can be created and sustained, post-harvest losses can be reduced, quality can be enhanced and smallholders can be integrated into market economy. Some of the action points for promotion of farm mechanization in rainfed areas are:

- Increasing the reach of farm mechanization to small and marginal farmers with cost effective, energy efficient and crop-specific farm equipment.
- Innovative custom service on rental model by institutionalization for high cost farm machinery viz., combine harvester, laser guided land leveller, rotavator etc., for small and marginal farmers.
- Creating hubs for hi-tech & high value farm equipment with respect to vegetables and fruit crops.
- Creating awareness among stakeholders through demonstration and capacity building activities.
- Ensuring performance testing and certification at designated testing centers.
- Need for strengthening training programmes for different stakeholders on operation, repair and maintenance of agricultural machinery, tractors, power tillers, combines etc.
- Increase in average supply of power to agriculture to about 2.5 kW/ha by 2025.
- Establishing a Model Custom hiring, training and maintenance centre.
- Developing entrepreneurship of unemployed rural youth.

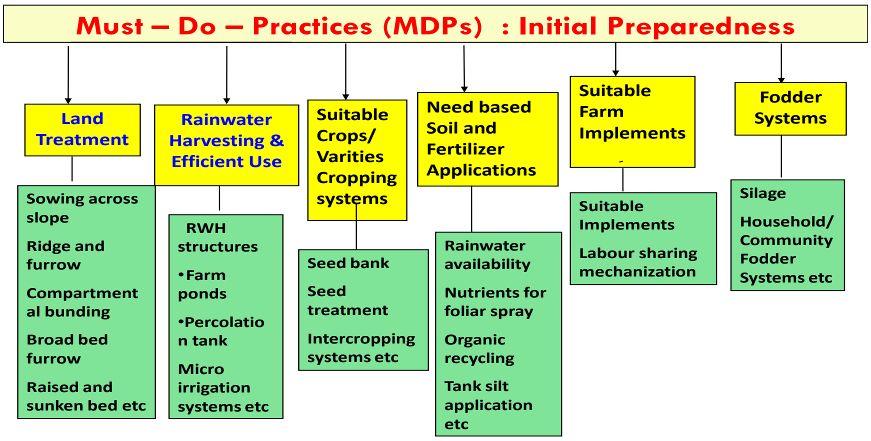
2.4.14. Drought proofing through real-time contingency plan implementation

The Real Time Contingency Planning (RTCP) conceptualized through All India Coordinated Research Project for Dryland Agriculture (AICRPDA) aims first to establish a crop with optimum plant population during the delayed onset of monsoon, to ensure better performance of crops during seasonal drought and extreme events, enhance performance, improve productivity and income and to enhance the adaptive capacity of the small and marginal farmers. The RTCP approach is two pronged viz.

i) Preparedness.
ii) Implementing contingency measures on real-time basis.

The preparedness emphasizes on a combination of tolerant variety/crop/ system, rainwater/soil/crop/nutrient management practices along with timely availability of inputs while real-time basis implementation focus on the crop/soil/moisture /nutrient management measures to cope with delayed onset of monsoon, seasonal drought, floods and other extreme events (AICRPDA-NICRA Annual Report 2013).

RTCP - Implementation process: RTCP - Initial preparedness to cope with drought: The must-to-do practices for initial preparedness or RTCP implementation are shown in the following figure.



RTCP Implementation: Role of village institutions: A Village Level Institution (VLI) is a formal body intended to ensure sustainable agriculture and rural development in India. The very purpose of forming VLI is to provide people ownership of any development project by making them an integral part of decision-making, giving them control over their resources, autonomy to implement the project, and carry on the process even after the completion of such projects. The VLIs like Village Climate Risk Management Committee (VCRMC), Custom Hiring Centre (CHC), Seed bank, Fodder bank etc. have a greater role to play in the initial preparedness for implementation of real time contingency planning.

RTCP- Key interventions
The following are the suggested key interventions to cope with delayed onset of monsoon, early/midseason/terminal drought

Delayed onset of Monsoon: Beyond the sowing window, choice of alternate crops or cultivars – matching farming situation, soil, rainfall and cropping pattern in the location and extent of delay in the onset of monsoon

Early Season Drought : i) Resowing within a week to 10 days with subsequent rains for better plant stand when germination is less than 30 per cent , ii) Thinning in small-seeded crops, iii) Inter-cultural operations to break soil crust and remove weeds and create soil mulch for conserving soil moisture, iv) Avoid top dressing of fertilizers till favourable soil moisture, v) Opening conservation furrows, vi) Gap filling when the crop stand is less than 75 per cent in crops like cotton and vii) Foliar spray with K based chemicals during prolonged dry spells

Midseason drought: i) Providing life-saving or supplemental irrigation, if available, ii) Harvesting crop at physiological maturity with some realizable yield or harvest for fodder, iii) Prepare for *rabi* sowing in double- cropped areas

RTCP Implementation: Constraints and opportunities
Constraints: i) Unavailability of seed of alternate crop/variety in sufficient quantities, ii)

Unavailability of suitable sowing implement

Opportunities: i) Production of seed of alternate crops/varieties by State Seed Corporations (SSCs), State Agricultural Universities (SAUs), KVKs etc.: Seed multiplication programmes in SSCs, SAUs etc. have greater role to provide suitable drought tolerant and short duration seed material during the event of delayed onset of monsoon, ii) Establishment of community/village seed banks for production and distribution of quality seeds , iii) Promote use of appropriate sowing implements for timely and precision sowing

Early season drought:
Constraints: i) Unavailability of seed of alternate crop/variety in sufficient quantities, ii) Lack of suitable implements for sowing, interculture and furrow opening in different crops, iii) Unavailability of harvested water for supplemental irrigation, pot watering in widely spaced crops, and foliar sprays

Opportunities: i) Production of seed of alternate crops/varieties by State Seed Corporations, SAUs, KVKs etc., ii) Promote use of suitable farm implements for sowing/interculture , iii) Rainwater management interventions like water harvesting and storage structures are capital and labour intensive. Thus, can be converged with MGNREGA and DRDA (District Rural Development Agency) programmes in a district.

Midseason drought and terminal drought
Constraints: i) Lack of suitable implements for interculture and foliar sprays in different crops, ii) Unavailability of harvested water for supplemental irrigation, pot watering in widely spaced crops and, foliar sprays, iii) Timely unavailability of inputs for foliar sprays

Opportunities: i) Promote use of suitable farm implements for different operations. CHCs have a greater role to play in implementation of RTCP measures including seed and fertilizer application, *in-situ* moisture conservation practices, water lifting with energy efficient pumps and efficient application, foliar sprays, residue incorporation etc., ii) Construction of farm ponds for efficient rainwater harvesting and reuse, iii) Efficient utilization of stored rainwater in farm ponds with micro-irrigation systems could be converged with government schemes like NHM, SHM etc. iv) Timely procurement and supply of inputs like KNO_3, thiourea, KCl etc. for foliar sprays , v) Efficient recycling of crop residues for mulching between crop rows

2.5. Capacity building

There is need to improve the capacities of local communities and local governments including the states, which are chronically drought prone. By involving communities in disaster management planning at the local level preparedness planning, they can be enabled to gain better understanding. Drought preparedness planning will increase the society's capacity to cope more effectively with the extremes of climate.

There is also need for a long-term strategy to build the capacities of local governments. It is also necessary for the local governments to collaborate with community based organizations/NGOs in identified areas within the broad spectrum of drought risk mitigation. A clear identification of roles and responsibilities would certainly enhance the local capacities to deal with the future risks. Moreover, capacity building is needed for research, development and upscaling of drought management capabilities of various stakeholders.

2.6. Government initiative

Climate change has already demonstrated its adverse impact on rainfed agriculture. The prevalence of extreme events and increased unpredictability of weather patterns can lead to reductions in production and lower incomes in these areas. Concerning the impact of climate change on rainfed agriculture, Government of India has emphasized on high priority on research and development to cope with climate change in agriculture sector.

Given the context, ICAR launched a mega project '*National Initiative on Climate Resilient Agriculture*' (NICRA) to enhance the resilience of Indian agriculture, covering crops, livestock and fisheries to climatic variability and climate change through development and application of improved production and risk management technologies; to demonstrate the site specific technology packages on farmers' fields for adapting to current climate risks; and to enhance the capacity of scientists and other stakeholders in climate resilient agricultural research and its application.

The thrust areas covered are, (i) identifying most vulnerable districts/regions, (ii) evolving crop varieties and management practices for adaptation and mitigation, (iii) assessing climate change impacts on livestock, fisheries and poultry and prioritising adaptation strategies.

Enhancing food security while contributing to mitigation of climate change and preserving the natural resource base and vital ecosystem services requires transition to agricultural production systems that are more productive, use inputs more efficiently, have less variability and greater stability in their outputs, and are more resilient to risks, shocks and long-term climate variability. More productive and more resilient agriculture requires a major shift in the way land, water, soil nutrients and genetic resources are managed to ensure that these resources are used more efficiently.

Development of crops and varieties adapted to climatic stresses is an important activity under NICRA. To address this objective, major food and horticultural crops are being evaluated for tolerance to abiotic stresses (drought, heat, flooding, salinity). Work on genetic enhancement has been carried out in a multi-institutional and multi-disciplinary network mode during the year. Wheat, rice, maize, pigeonpea, mango and tomato are being focussed.

2.7 Strategic Research needed to develop Climate Resilient Varieties

The whole concept of farming revolves around the seed. Identification of crops and varieties that fit well into changed climatic conditions is common denominator for sustainable crop production in all agro-ecosystems. An ideal variety should be high yielding, and plastic enough to withstand against weather aberrations, tolerant to multiple abiotic and biotic stresses, responsive to augmented CO_2 levels and fit well to farming situations.

The choice of crops and varieties is more relevant under highly complex rainfed production systems and areas frequented with weather vagaries. The choice of the crops and variety for an agro-ecosystem could further be narrowed down by matching crop requirements with prevailing location specific climatic and soil information. These eco-systems require highly elastic crop and varieties which could give higher yields under normal conditions and also withstand the natural calamities effectively.

By understanding special needs of such agro-ecosystems, a number of crop varieties have been developed and evaluated for their suitability in different parts of the country. Generally, the crop for rainfed areas should be of short duration with early vigour, deep root system with ramified roots, dwarf plants with erect leaves and stem, moderate tillering in case of tillering crops and varieties, resistance/tolerance to biotic stresses, lesser period between flowering and maturity so that the grain filling is least affected by adverse weather, resistance/tolerance to abiotic stresses, low rate of transpiration, less sensitive to photo-period and wider adaptability. Thus, under changing climate conditions, introduction of high yielding, drought resistant/tolerant varieties hold the promise for getting higher yields.

The National Agricultural Research System (NARS) comprising ICAR and Agricultural Universities are taking adequate steps to develop high yielding varieties suitable for biotic and abiotic stresses including deficient rainfall/drought situations.

Further, short duration varieties have also been released to escape the vagaries of weather condition. The efforts are also being made to develop /identify climate resilient varieties to cope with multiple stresses under the ICAR flagship project on National Innovations on Climate Resilient Agriculture (NICRA).

The immediate strategy in NARS and NICRA could be developing and / or identifying the existing elite germplasm for a specific abiotic/biotic stress and or for multiple stresses. The type of abiotic stresses in major crops and the research needs to cope with such abiotic stresses are given in Table 2.4.

Table 2.4. Type of climate vulnerability of various crops and research needs

Crop	Abiotic stress	Region	Research needs for developing new cultivars and or screening the existing elite germplasm for
Wheat	Drought and heat stress	Northern, western and central India	Drought and heat tolerance
	Drought	Central India	
	Heat stress	Western India like the state of Gujarat and Rajasthan	Heat tolerance
	Salinity	UP, MP, and parts of Haryana	Salinity tolerance
Rice	Flood, drought	Northern, western and central India	Flood, submergence and heat tolerance

Crop	Abiotic stress	Region	Research needs for developing new cultivars and or screening the existing elite germplasm for
	Cold stress	Assam and hills valley areas where rice is cultivated.	Cold tolerance
Maize	Drought and heat stress	During *kharif* mostly in southern states	Drought and heat tolerance
	Water logging	Many parts of the country	Water logging/excess moisture tolerance
Sorghum	Drought	Karnataka, Maharashtra and other parts of the country	Drought tolerance, early maturity for post rainy season sorghum in northern Karnataka & Madhya Maharashtra
Pearl millet	Drought and heat stress	Gujarat, Rajasthan, Haryana, Central U.P	Early maturity, heat tolerance
Pulses	Drought	During *kharif* in pulse growing regions under rainfed condition	Early maturity, drought tolerance
	Heat stress (Summer greengram, blackgram)	North India	Heat tolerance, early maturity
	Terminal drought (pigeonpea)	Pigeonpea growing regions under rainfed condition	Extra early maturity
	Cold stress (Pigeonpea and chickpea)	North India	Cold tolerance, extra early maturity
	Terminal heat stress (chickpea)	North India	Early maturity
	Salinity, alkalinity	Indo-gangetic plains, irrigated command areas	Salinity and alkalinity tolerance
Oilseeds	Drought, high temperature, salinity and cold stress (rapeseed &mustard, most susceptible to drought)	Oilseeds growing regions under rained condition	Early maturity, tolerance to drought, high temperature, salinity , cold
Cotton	Drought, water logging/excess moisture/ high temperature	Cotton growing areas in the country	Early maturity and tolerance to excess moisture /waterlogging , high temperature

2.8. Annotation

Rainfed agriculture is important for the country's economy and food security since it contributes to about 40 per cent of the total foodgrain production, supports two-thirds of livestock and 40 per cent of human population. The state of rainfed agriculture is precarious and the problems associated with it are multifarious such as scarcity of water, low cropping intensity, high cost of cultivation, poor adoption of modern technology, uncertainty in output, increasing number of suicides among farmers, lack of institutional credit, inadequate public investment and high incidence of rural poverty.

A holistic development including of rainfed agriculture is warranted for improving sustainability. Particular emphasis should be placed on stabilization of crop productivity through improved crop management and cultivar selection, Agro-ecology specific rainwater management practices, adoption of water saving technologies *viz*., drip & sprinkler irrigation in commercial field & horticultural crops, efficient intercropping system, dryland horticulture, fodder production and animal husbandry etc.

Besides this, develop site specific Real Time Contingency Planning (RTCP) to ensure better performance of crops during seasonal drought and extreme events, and to enhance the adaptive capacity of the small and marginal farmers. To this end, farmers need to intelligently adapt to the changing climate in order to sustain crop yields and farm income. Enhancing resilience of agriculture to climate risk is of paramount importance for protecting livelihoods of small and marginal farmers.

Key Extracts

- Rainfed agriculture offers food and livelihood security to a large number of populations in the country.
- Multipronged challenges including water scarcity, climatic variability, and inadequate adoption of modern technologies due to poor socio economic status affect rainfed agriculture.
- To attain sustainability in rainfed agriculture, higher emphasis should be placed on water harvesting and adoption of water saving technologies *viz*., drip & sprinkler irrigation, abiotic stress tolerant cultivars, and Real Time Contingency Planning (RTCP) to ensure better performance of crops during seasonal drought and extreme events.
- Climate change has become a reality and calls for strategic climate resilient practices.

Chapter 3
Organic Farming

Organic agriculture has a history of being contentious. Organic agriculture, sometimes called biological or ecological agriculture, is still considered by some critics as being an inefficient approach to food security; and that as a farming system it will become less relevant in the future. In contrast, it is also believed by another school that it could offer solution to soil fatigue that comes from industrial agriculture. This is manifest in the steady increase over the recent years in the number of organic farms, the extent of organically farmed land, the amount of research funding devoted to organic farming and the market size for organic foods. The demand for organic foods also emanates from the desire for toxic-free safe food.

3.1. Introduction

Organic agriculture is recognized as an innovative farming system, that balances multiple sustainability goals and will be of increasing importance in global food and ecosystem security (Reganold and Wachter, 2015). High demand for organic foods in Europe and North America has resulted in the import of organic foods from large farms. Organic agriculture relies on location specific varieties (resistant/tolerant to pest and diseases), crop rotation, organic composts, green manure, biological pest management and prohibits the use of synthetic fertilizers and pesticides, antibiotics, genetically modified organisms, and growth hormones. Concerns about the un-sustainability of conventional agriculture (based on synthetic inputs) have promoted interest in other farming systems, such as organic, integrated and conservation agriculture (CA).

Organic farming has the potential to produce high quality food, enhance natural resource base and environment, increase income (coming from premium price on the produce, even in the face of a slight dip in the yields) and contribute to the wellbeing of the farmers. Under extreme climatic conditions such as drought which are expected to increase with climate change, organically managed farms may produce higher yields than their conventionally managed farm due to improvement in soil properties (Das et al., 2016). Under severe drought conditions, which are expected to increase with climate change in many areas, organically managed farms have frequently been shown to produce higher yields than their conventionally managed farms due to the higher water-holding capacity of organically farmed soils (Siegrist et al., 1998). In addition, improvements in management practices and location specific crop varieties for organic systems may also narrow down this yield gap.

Organic farming system may also have higher soil organic carbon (SOC) levels, better soil quality and less erosion than conventional systems (Lynch et al., 2012). With respect to nitrate and phosphorus leaching and greenhouse gas (GHG) emission, organic farming scores better than conventional farming in respect to per unit production area (Skinner et al., 2014). Similarly, organic systems are reported to be more energy efficient than their conventional counterpart. The generally lower energy use and mostly higher SOC under organic systems make them ideal an blueprint for developing methods to limit fossil fuel emission and build SOC reserve, important tools in addressing climate change. Use of appropriate crop varieties, organic manure, residue retention, reduced tillage, inclusion of legume in cropping system and other soil and water conservation practices can contribute to improvement in soil properties and climate resilient agriculture. However, there are reports that application of organic manure, mulching, etc. does not always sequester more SOC. This is because, C added in manure, mulch and compost comes from another land and is not based on plants produced on the same land unit. Adequately designed organic farming practices comprising application of right kind/quantity of organic manure and amendments (like biochar, lime, rock-phosphate etc.), reduced tillage/no-till, crop (or weed) residue retention and crop rotation can strongly improve C-sequestration and reduce green house gases (GHG) emission from farmland due to favourable changes in soil properties, and bio-chemical processes within the soil. Many farms in both developed and less-developed countries implement organic practices but are not certified organic. However, growers are increasingly turning to certified organic farming systems as a way to provide verification of production methods, decrease reliance on non-renewable resources, capture high-value markets and premium prices, and boost farm income.

3.2. Organic and Towards Organic Agriculture

Organic farming is to create integrated, humane, environmentally and economically sustainable production systems, which maximize reliance on farm-derived renewable resources and the management of ecological and biological processes and interactions. The purpose is to realise acceptable levels of crop, livestock and human nutrition, protection from pests and disease, and an appropriate return to the human and other resources. Organic farming provides long-term benefits to people and the environment. There are two significant areas where organic systems have higher yields compared to conventional systems. These are:

- under conditions of climate extremes; and
- in small holder systems.

Both these situations are critical to achieving safe food security for future in India. Organic farmers grow a variety of crops and raise livestock in-order to optimize competition for nutrients. This results in less chance of low production, improved availability and positively impact local food security. Studies by national and international agencies have proved these positive aspects of organic agriculture systems.

Organic is more of a description of the agricultural methods used on a farm, rather than food itself and those methods combine tradition, innovation and science. Organic agriculture, in simple terms, requires a shift from intensive use of synthetic chemical fertilizers, insecticides, fungicides, herbicides, plant growth regulators (PGRs), genetically engineered plants to extensive use of animal manures, beneficial soil microbes, bio-pesticides, bio-agents and indigenous technological knowledge based on scientific principles of agricultural systems. Scientific evidences clearly establish that conversion of high intensive agriculture areas to organic systems lead to reduction in crop yields considerably (upto 25-30 per cent), especially during initial 3-4 years of conversion phase; before soil system regains and crop yields climb up to comparable level. In this scenario, if all the cultivated areas are brought into organic production systems, the national food production system may get jeopardized; hence a cautious approach is desirable.

Weighing this fact against the global scenario of organic agriculture, the **Working Group on Horticulture, Plantation Crops and Organic Farming for the XI-Five-Year Plan suggested a spread of organic farming on 1-5 per cent area in the high productive zones and larger spread in the less exploited areas, such as, rainfed and hill areas**. Further, integrated approach to crop management – including integrated nutrient management (INM) and inter/mixed cropping – is also considered as **"towards organic"** approach; and at the same time has been found to increase the use efficiency of all costly inputs, especially fertilizers and water.

In balance, it appears to be more reasonable to adopt a mix of the above two approaches, so that India's food security is ensured. This approach will also contribute to **'more crop & income per drop of water, per unit of resource and per unit of land'** strategies of the government. There are large tracts which are less endowed in terms of soil & water and scope for adoption of intensive resource use based agriculture is less. In fact, many in these areas practise organic farming by default. However, the farming practice needs to be modernized which will result in yields higher than now being realised.

India has a sizable extent of cropped area in different states, which is more prone to weather vagaries; especially those located in rainfed, dryland and hilly areas. Increasing the agricultural productivity and income of the farmers as well as sustaining soil resource in these agricultural systems has always been a challenging task for researchers and policy planners. Presently, in these areas use of fertilizers and pesticides is minimal and is much below the national average. To begin with, these are the areas which need to be targeted for organic production by devising proper strategies and identifying niche crops (crops which yield higher under organic production systems and have adequate market demand).

Both domestic and export markets need to be targeted for increasing the income of the farmers, as it is important to note that 78 per cent of Indian organic consumers prefer Indian brand of organic and many other countries also require diversified organic foods of tropical fruits, vegetables, essential oils, flowers, herbs, spices and organic cotton from India. In addition, large-scale adoption of organic agriculture in such areas will not only help in conserving the environmentally fragile ecosystems but also help in supplementing overall food production of the country. This can be clearly brought out by the example of Sikkim located in the north-eastern hill region of the country. During 2002-03 (before Sikkim Organic Mission) when fertilizer consumption was as high as 21.5 kg/ha, the productivity of rice was 1.43 t/ha, but 11 years later, i.e., during 2013-14, it increased to 1.81 t/ha, and more interestingly, no yield reduction was observed during conversion period. Productivity increases in other crops was also noted to the tune of 11 per cent, 17 per cent and 24 per cent in maize, finger millet and buckwheat, respectively. It was a clear demonstration, that with improved farm management practices, yield levels can be substantially increased even under organic farming practices, in regions where average yields are lower than national averages.

3.2.1. Organic farming: concepts

The concept of organic farming is based on the following principles:

- Nature is the best role model for farming, since it does not use any input(s) nor demands unreasonable quantities of water.
- The entire system is based on intimate understanding of nature's ways. The system does not believe in mining of the soil of its nutrients and does not degrade it in any way for today's needs.
- The soil in this system is a living entity and the soil's living population of microbes and other organisms are significant contributors to its fertility on a sustained basis and must be protected and nurtured at all cost.
- The total environment of the soil, from soil structure to soil cover is more important.

3.2.2. Organic farming: focus

Organic agriculture is a holistic production management system which promotes and enhances health of the agro-ecosystem, including bio-diversity, biological cycles, and soil biological activity. Its emphasis is on the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems. This is accomplished by using, where possible, cultural, biological and mechanical methods, as opposed to using synthetic material, to fulfil any specific function within the system. Organic farming aims to optimize quality in all aspects of agriculture by taking into consideration the natural capacity of plants, animals and the land. It emphasizes on the health of agricultural ecosystem and prohibits the use of synthetic herbicides and pesticides, synthetic fertilizers in crop production and hormones antibiotics in livestock production, and genetically modified organisms. It respects the law of nature to increase yields and disease resistance. Organic farming requires a high level of farm management skills and demands use of wide range of resources to solve the problems. The organic farming focuses on:

- Maximization of biological activity in soils.
- Maintenance of long term soil health and minimization of soil erosion.
- Enhancing genetic and biological system and the surroundings.
- Raising of livestock with optimal living conditions for well -being and better health.
- Recycling of materials of plant and animal origins, nutrients to the soil.
- Minimization of the use of non-renewable resources.

3.2.3. Principles of organic farming

It aims to work as much as possible within a closed system, and draw upon local resources with a view to:

- maintain the long-term fertility of soils;
- avoid all forms of pollution that may result from agricultural techniques;
- produce foodstuffs of high nutritional quality and sufficient quantity;
- reduce the use of fossil energy in agricultural practice to a minimum;
- give livestock conditions of life that confirm to their physiological need; and
- make it possible for agricultural producers to earn a living through their work and develop their full human potential.

Principles of organic agriculture, scope and objectives
The organic community has adopted four basic principles (FAO 2001), and broadly speaking, any system using the methods of organic agriculture and being based on these principles, may be classified as organic agriculture:

- **The principle of health:** Organic Agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible.
- **The principle of ecology:** Organic Agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them.
- **The principle of fairness:** Organic Agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities.
- **The principle of care:** Organic Agriculture should be managed in a precautionary and responsible manner to protect the health and wellbeing of current and future generations and the environment.

Organic farming is considered incomplete without livestock, as this alone contributes 37.5 per cent of the total organic manures in the country. The predominant farming system practised traditionally by Indian farmers over the centuries is a mix of crop and dairy, and this needs to be further strengthened.

The yield level of organic agriculture is lower in some of the crops in the initial years compared to cultivation systems based on agro-chemicals. However, it may be more practical to compare the organic agriculture yield with the average yield obtained under farmer's package of nutrient management, and aim at realising higher yields by adopting scientific principles of organic farming. Organic farming principles aim at:

- Production of high quality food in sufficient quantity in harmony with natural systems and cycles.
- Enhancing biological cycles within the farming system involving microorganisms, soil flora and fauna, plants and animals.
- Maintaining long-term soil fertility and genetic diversity of the production system and its surroundings including plant and wildlife.
- Promoting healthy use with proper care of water resources and all life therein.
- Creating harmonious balance between crop production and animal husbandry.
- Minimizing all forms of pollution.

3.3. Composting of Wastes and Recycling under Organic Farming

Good quality compost free from weeds & pathogens and rich in nutrients is a prerequisite for adopting organic farming practice. Different methods have been developed for the preparation of quality compost from farm wastes. Several methods of composting of farm wastes exist in India. Production and nutrient content of various composts in India is given in Table 3.1**.** Government has established 19 fruit vegetable waste compost units in various states between 2004 to 2014 with a production capacity of 63,150 metric tonnes (MTs); and 50 bio-fertilizer units with a production capacity of 12,563 MTs under National Project on Organic Farming

(NPOF). Some of these are discussed in the following paragraphs.

Indore method: This is an old method of compost preparation in the pit of the size of 9'x5'x3'. A portion of the pit is filled with farm wastes, layer by layer. Each layer is around 3" thick and over it a layer 2" of cow dung slurry mixed with urine is spread. Pit is filled with farm wastes and plastered with 2"-4" thick layer of soil and dung. This prevents moisture loss and allows the temperature to rise up to 60-65ºC within 3-4 days. The material inside the pit is turned after 15-30 days and moisture is maintained by adding water. Another turning is given after an interval of 30 days. Good quality compost becomes ready within 3-4 months.

NADEP compost: This compost method was developed by Naryan Devrao Pandri Pandey. A brick structure measuring 10'x6'x3' is prepared with holes in the side walls to ensure adequate supply of air during composting. The brick tank is filled with farm wastes, soil and cow dung and water is added to maintain moisture between 60-75 per cent. A tank is filled with soil, 16-18 quintals (q), farm wastes 14-16 q, dung 1-1.2 q. Water is added to moisten the material and upper layer is plastered with soil and dung mixture. After 75-90 days of composting, microbial culture of *Azotobacter*, *Rhizobium* and phosphate solubilizing bacteria are added into the mixture. Compost becomes ready for use within 110-120 days. One tank provides about 2.5-2.7 t of compost, sufficient for one hectare land. Another kind of NADEP is known as BHU-NADEP. In this, bricks are not required for tank construction. Method of filling is same as above.

NADEP Phospho-compost: This is a method to prepare phosphorus enriched compost using farm wastes, rock phosphate and phosphate solubilizing bacteria. Insoluble phosphorus present in rock phosphate is transformed into soluble form through the action of certain specific microorganisms during the process of composting. Compost is prepared using farm wastes, cow dung and soil as the quantity given for preparation of NADEP compost. Rock phosphate is added to this mixture @ 12.5 per cent w/w. This mixture is filled either in pit, NADEP tank or BHU-NADEP. This material is plastered with a mixture of dung and soil after adding sufficient water to moisten the decomposing mixture. The material is turned after 15 days and thereafter at an interval of 30 days. At each turning, water is added to maintain sufficient moisture. Compost becomes ready within 3-4 months and contains N 1 per cent, P_2O_5 2-4 per cent and K_2O 1-2 per cent. On equal P_2O_5 basis, this compost can substitute the use of phosphatic fertilizers in crops.

Institute of Biological Sciences (IBS) - Rapid Composting Technology: This technology involves inoculating the plant substrates with cultures of a cellulose decomposing fungus (*Trichoderma harzianum*) for composting. Sawdust mixed with the leaves of subabul (*Leucaena leucocephala*), a leguminous tree, is used as the medium of growth for compost fungus activator. The composting time, using this procedure, ranges from 21 to 45 days, depending on the kind of plant substrates used. The procedure consists of two parts: the production of the compost fungus activator and the composting process. Substrates such as rice straw, weeds and grasses should be chopped as this helps speed up decomposition by increasing the surface area available for microbial action, and providing better aeration. If large quantities of substrates are to be used (several tons), a forage cutter/chopper is needed. Substrates should be moistened with water. If large volume of substrates are to be composted, a sprinkler is more convenient. Carbonaceous substrates should be mixed with nitrogenous ones in a ratio of 4:1 or less, but never lower than 1:1 (on a dry weight basis). Some possible combinations are: **(i)** 3 parts rice straw :1 part subabul, **(ii)** 4 parts rice straw:1 part chicken manure, **(iii)** 4 parts grasses:1 part legume materials + 1 part manure and **(iv)** 4 parts grasses: 1 part *Chromolaena odorata* or *Mikania cordata* (weeds) + 1 part animal manure. The substrates should be piled loosely to provide better aeration within the heap. Compost heaps should be located in shady areas such as under big trees. The platform should be raised about 30 cm from the ground, to provide adequate aeration at the bottom. Alternatively, aeration can be provided by placing perforated bamboo trunks horizontally and vertically at regular intervals, to carry air through the compost heap. The compost fungus activator is broadcasted onto the substrates during piling. Once decomposition is complete, the compost should be sun dried again until its moisture content is 10- 20 per cent. If mature compost is needed at once, it should be sun dried for one day, or as soon as its temperature drops to 30°C.

Coir pith compost: Large quantity of coir waste of about 7.5 million tonnes (mt) is available annually in the country from coir industries. Coir fibre is usually used in rope making industries which generates bulk amount of dusty materials called coir dust/coir pith. Composting of coir pith reduces its bulkiness, C:N ratio, lignin and cellulose contents and increases its manurial value. Coir pith composting is an aerobic composting. Thus, a heap of 4' x 3' x 4' (LxWxH) is made. Initially coir pith should be put upto 3" height and thoroughly moistened. Then nitrogenous source may be added in the form of fresh poultry litter @200 kg/t. Microbial inoculums, namely, *Pleurotusspps* was added. For maintaining aerobic condition, turning (once in 10 days) is done. Sixty per cent moisture is to be maintained at the time of composting. The matured compost is ready to use within 60 days.

Sugarcane trash compost: Sugarcane produces about 10 to 12 metric tonnes of dry leaves/ha. Its trash contains 28.6 per cent organic carbon, 0.35 to 0.42 per cent nitrogen, 0.04 to 0.15 per cent phosphorus and 0.50 to 0.42 per cent potassium. Sugarcane trash can be easily composted by using the fungi like *Trichurus, Aspergillus, Penicillium* and *Trichoderma*. For one ton of sugarcane trash 50 kg fresh dung is recommended. The dung can be mixed with 100 litres of water and thoroughly mixed with sugarcane trash. Rock phosphate @ 5kg/ton of waste and inoculums @ 2kg/ton can be added. After mixing all the inputs with sugarcane trash, heap should be formed with a minimum height of 4'. This height is required to generate more heat in the composting process, and the generated heat will be retained long time inside the material. The composted material should be turned periodically once in 15 days for better aeration.

Press-mud compost: Press-mud is a by-product obtained from sugar industry. About 3 per cent of press-mud is obtained for the total quantity of cane crushed. Press-mud is spread in the compost yard to form a heap of 9' x10.5' x4.5' (LxWxH). Distillery effluent is sprayed on the heaps to a moisture level of 60 per cent and the press-mud heap is allowed overnight to absorb the effluent. Bacterial culture was diluted with water (1:10) and added @ 10 L/t. after 3 days. Depending on the moisture content of the heap, the effluent should be sprayed once or twice in a week. This should be repeated for 8 weeks so that the press-mud and effluent proportion reaches an optimum ratio of 1:3. The heaps are then allowed for one month of curing. The bio-inoculants such as *Azotobacter* can be added to enrich the compost for nitrogen and the introduction of phosphorus solubilizing microorganisms like *Aspergillus awamori* or *Bacillus polymyxa* will improve the available phosphorus content in the manure.

Poultry waste compost using paddy straw: Fresh poultry droppings are mixed thoroughly with chopped paddy straw (< 2 cm size) @ 1:1.25 ratio. *Pleurotussajorcaju* is inoculated @ 5 packets (250 g each) /t of substrate. Periodical watering should be done once in 15 days and turning should be given on 21^{st}, 35^{th} and 42^{nd} day of composting (avoid turning during first 3 weeks of composting). Materials are converted to matured compost within a period of 50 days.

Vermicompost: Earthworms are used to prepare compost from farm and livestock wastes. Earthworms continuously feed upon the organic residues and produce casts, which generally termed as vermicompost. Casts of earthworms are usually rich in nutrients, specially micronutrients and enzymes, and organic matter and therefore serve as a good source of manure for growing crops. Certain earthworms like *Eisenia foetida*, *Perionyx excavatus* and *Eudrilus eugeniae* are specifically suited for the preparation of vermicompost. Vermicompost contains 1.0-1.5 per cent N, 0.2-1.0 per cent P_2O_5, and 1-2 per cent K_2O. depending upon the raw materials used.

Table 3.1 Production and nutrient content of various composts in India.

Compost	**Production potential (t)**	**N (per cent)**	**P_2O_5 (per cent)**	**K_2O (per cent)**	**C:N ratio**
Coirpith compost	4.0	1.24	0.06	1.21	24:1
Pressmud compost	2.0	2.70	3.00	3.00	10:1
Poultry waste compost	2.5	1.89	1.83	1.34	12:1

Pitcher khad: This is a fermented preparation made from cow dung (15kg), cow urine (15 litres), water (15 litres) and jaggery (250g). These are mixed in a container and covered with a cloth or gunny bag. The material is fermented for 4-5 days. The fermented mixture is mixed with 200 litres of water and sprayed over the crop in one acre area. Two -three such sprays are sufficient for short duration crops.

Bio-gas slurry: Bio-gas slurry prepared from livestock wastes is a good manure. Slurry is dried in solar drier and the dried slurry is directly applied in fields.

3.4. Various forms of Organic Agriculture

3.4.1. Bio-dynamic agriculture

Bio-dynamic agriculture is a method of farming that aims to treat the farm as a living system which interacts with the environment, to build healthy & living soil and to produce food that nourishes and vitalizes and helps to develop mankind. The underlying principle of bio-dynamics is making life-giving compost out of dead material. The methods are derived from the teachings of Rudolf Stainer and subsequent practitioners. These bio-dynamic preparations named BD-500 to BD-507 are not food for the plants, but they facilitate effective functioning of etheric forces. They are also not the usual compost starters, but can stimulate compost organisms in various ways. In short, they are biologically active dynamic preparations which help in harvesting the potential of astral and etheral powers for the benefit of the soil and various biological cycles in the soil. So far, 9 bio-dynamic preparations have been developed, named as formulations 500 to 508. Out of these, formulation-500 (cow horn compost) and formulation- 501 (horn-silica) are very popular and are being used by large number of organic farmers. Formulations-502 to 507 are compost enrichers and promoters, while formulation 508 is of prophylactic in nature and helps in control of fungal diseases.

3.4.2. Rishi krishi

Drawn from Vedas, the Rishi Krishi method of natural farming has been mastered by farmers of Maharashtra and Madhya Pradesh. In this method, all on-farm sources of nutrients including compost, cattle dung manure, green leaf manure and crop bio-mass for mulching are utilised to their best potential with continuous soil enrichment through the use of Rishi Krishi formulation known as "*Amritpani*" and virgin soil. A quantum of 15 kg of virgin rhizosperic soil collected from beneath the banyan tree (*Ficus bengalensis*) is spread over one acre and the soil is enriched with 200 lit *Amritpani*. It is prepared by mixing 250 g ghee into 10 kg of cow dung followed by 500 g honey and diluted with 200 lit of water. This formulation is utilized for seed treatment (*beejsanskar*), enrichment of soil (*bhumisanskar*) and foliar spray on plants (*padapsanskar*). For soil treatment it is need to be applied through irrigation water as fertigation. The system has been demonstrated on a wide range of crops i.e. fruits, vegetables, cereals, pulses, oilseeds, sugarcane and cotton.

3.4.3. Panchgavya krishi

Panchgavya is a special bio-enhancer prepared from five products - cow dung, urine, milk, curd and ghee. The cost of production of panchgavya is about Rs. 25-35 per lit. Panchgavya contains many useful micro-organisms such as fungi, bacteria, actinomycetes and various micronutrients. The formulation acts as a tonic enriching the soil, inducing plant vigour with quality production. The time of application of *panchagavya* in various crops is given in Annexure 1.

3.4.4. Natural farming

Natural farming that goes beyond organic farming, emphasizes on efficient use of on-farm biological resources and enrichment of soil with the use of *Jivamruta* (fermented microbial culture used for soil enrichment) to ensure high soil biological activity. Use of *Bijamruta* (fermented microbial culture used for soil enrichment) for seed/ planting material treatment and *Jivamruta* for soil treatment and foliar spray are important components of natural farming. Jivamruta has been found to be rich in various beneficial micro-organisms. One application in one acre requires 200 litres of jivamruta. It can be applied through irrigation water by flow, by drip or sprinkler or even by drenching of mulches spread over the field or under the tree basin.

3.4.5. Natu-eco farming

The Natu-eco farming system follows the principles of eco-system networking of nature. It goes beyond the broader concepts of organic or natural farming in both philosophy and practice. It offers an alternative to the commercial and agro-chemical intensive techniques of modern farming. Instead, the emphasis is on the simple harvest of sunlight through the critical application of scientific examination, experiments, and methods that are rooted in the neighbourhood resources. It depends on developing a thorough understanding of plant physiology, geometry of growth, fertility, and biochemistry. Natu-eco Farming emphasizes **`Neighbourhood Resource Enrichment**' by **`Additive Regeneration**' in preference to dependence on external commercial inputs. The three relevant aspects of Natu-eco Farming are:

- Soil **-** Enrichment of soil by recycling of the bio-mass by establishing a proper energy chain.
- Roots **-** Development and maintenance of white feeder root zones for efficient absorption of nutrients.
- Canopy **-** Harvesting the sun through proper canopy management for efficient photosynthesis.

In all biological processes, energy input is required and solar energy is the only available & sustainable resource. No time and no square foot of sun energy should be lost by not harvesting it biologically. **Lost sun energy is lost opportunity**. Photosynthesis is the main process by which Solar Energy is absorbed. It is of course the objective to obtain a higher degree of photosynthesis. Although, genetically photosynthesis efficiency is around 1.5 per cent to 2.5 per cent, one can increase leaf index [area of leaf for every square meter of land] by caring for healthy canopies, use of multiple canopy utilizing direct and filtered sunrays.

3.5. Practical Production Issues and Strategies for Success

Fertility management in different types of soils is very crucial and critical to increasing the productivity under organic farming. The most challenging time in the organic farming system is the transition phase, as the farmers switch from conventional to organic agriculture. During the early stages of conversion, drop in yields upto 30 per cent has been reported by farmers who were earlier dependent on herbicides, fertilizers and pesticides and it takes about a decade for restoration of pre-conversion yield levels. But some farmers have observed that the yields rebound within just a few years as they were using only minimum inputs. The yields tend to increase with the number of years under organic management as farmers gain experience and soil improves. It has also been reported, that organic farms have higher yields than conventional farms under situation of stress caused by drought, heat, excessive rainfall or unreasonably cold weather. Organic farming tends to have lower cost of production than conventional farming, as there is less emphasis on purchased inputs. In result, the net income from organic farming appears to be slightly higher than the conventional farming, due to reduction in cost of cultivation and premium price that the organic produce fetches in the market. Although several issues exist for organic growers, practically there are three (3) major constraints to high productivity. These are:

Supply of sufficient nutrient through organic management: Crop needs nitrogen, phosphorus, potassium and several other secondary and micro-nutrients for assimilation and better bio-mass output. These nutrients need to be supplied in a form which does not have synthetics and does not cause environmental degradation. Organic farming discussion starts with the challenge of meeting the nutrient requirement of crops through organic manures and its sources. This has to be ensured.

Insect and disease management: is an important issue that is directly related to crop productivity and environment. It is generally believed, that a healthy plant grown in an organic environment is less vulnerable to pests and diseases. In addition, various mechanical & biological systems of pest and disease management practices will need to be adopted.

Weed management: is a major issue for many of the organic growers, as it has been observed that under organic management, weeds grow intensively when manures from outside the farm are used. Clean cultivation will be needed.

3.6. Strategies for Sustainability

3.6.1. Supply of sufficient nutrient through organic management

Enough scope for production of sufficient organic inputs exists in India. Among different sources, livestock accounts for major share (nearly 40 per cent). It is followed by crop residues (30 per cent) and other sources (15 per cent). Other sources include the rural compost, vermicompost and agricultural wastes. Further, the concept of promoting organic farming around individual crops should be avoided and it is better practised in cropping/farming systems. The issue of sufficient nutrient supply under organic systems can be addressed through following measures.

Organic farming is considered incomplete without livestock, as it alone contributes nearly 40 per cent of total organic manures in the country. Indian farming system practised over centuries is crop and dairy based. Analysis of farming systems practised by 732 marginal households across the 30 National Agricultural Research Project (NARP) zones has indicated existence of 38 types of farming systems. Of these, 47 per cent of households practise integration of crop + dairy; 11 per cent crop + dairy + goat; and 9 per cent households crop + dairy + poultry systems. Hence, there already exists a natural strength in the country for promotion of organic and towards organic agriculture.

Integrated Organic Farming Systems (IOFS)

IOFS models established at Coimbatore (Tamil Nadu) and Umiam (Meghalaya) under Network Project on Organic Farming (NPOF) have shown that organic farming system can improve the net returns by 3 to 7 times compared to existing systems and meet upto 90 per cent of seeds/planting materials, nutrients, bio-pesticides and other inputs within the farm in the three years of establishment (Table 3.2).

Table 3.2 Performance of integrated organic farming system models (Source: NPOF).

Components	Area (ha)	Total cost (Rs/year)	Net returns (Rs/year)				
			Crop	Livestock	Others	Total	Existing system
Coimbatore (Tamil Nadu)							
Crop (Okra, cotton, desmanthus) + dairy (1 milch animal, 1 heifer & 1 bull calf) + vermicompost + boundary plantation	0.40	1,10,109	64,500 (87 per cent)	8,216 (11 per cent)	1,600 (2 per cent)	74,316	27,200 *
Umiam (Meghalaya)							
Crops (Cereals + pulses + vegetables +fruits + fodder) + Dairy (1 cow + 1 calf) + Fishery + Vermicompost	0.43	56,654	47,487 (66.5 per cent)	17,065 (24 per cent)	6890 (9.6 per cent)	71,442	15,700 **

* finger millet – cotton - sorghum, ** rice-fallow (*Source*: NPOF)

Multiple cropping and crop rotation

Mixed cropping is an outstanding feature of organic farming in which variety of crops are grown simultaneously or at different time on the same land. Every year, care should be taken to maintain legume cropping over at least 40 per cent farm area. In selecting crop combinations, it is also to be kept in mind that there are certain plant compatibilities, which should be taken advantage of, e.g. maize gets along well with beans and cucumber, tomatoes go well with onions and marigold. On the other hand beans and onions do not go well with each other.

Direct seeded rice + soybean under organic management (Source: NPOF centre, Pantnagar)

The whole farm should have at least 8-10 types of crops at all the times. Each field/ plot should have at least 2-4 types of crops out of which one should necessarily be a legume. In case only one crop is taken in one plot, then adjacent plots should have different crops. For maintenance of diversity and pest control, vegetable seedlings can be planted randomly @ 50-150/acre which can be used for home consumption and 100 plants/acre of marigold in all crop fields. Such crops serve as alternate hosts, preventing pest attack on the primary crop. Crop rotation is the succession of different crops cultivated on same land. It is available to follow 3-4 years rotation plan. All high nutrient demanding crops should precede and follow legume dominated crop combination. Rotation of pest host and non pest host crops helps in controlling soil borne diseases and pests. It also helps in controlling weeds. It is better for improving productivity and fertility of soil. Crop rotations help in improving soil structure through different types of root system. Legumes should be used frequently in rotation with cereal and vegetable crops. Green manure crops should also find place in planning rotations. Principles with examples for selecting the crops and varieties for organic farming are given below (*Source*: NPOF).

- Non–leguminous crops should be followed by leguminous crops and vice-versa, *e.g.*, green gram – wheat / maize. If preceding crops are legume or non-legume grown as intercrops or mixed crops, the succeeding crop may be legume or non-legume or both.
- Restorative crops should be followed by exhaustive or non-restorative crops.eg. sesame – cowpea / green gram / Black gram / groundnut
- Leaf shedding crop should be followed by non-leaf shedding or less exhaustive crops.eg. pulses / cotton – wheat / rice
- Green manure crop should be followed by grain crops. *e. g*., Sesbania - rice, green gram/ cowpea – wheat / maize.
- Highly fertilized crops should be followed by less-fertilized crop. *e. g*., maize - black gram/gourds.
- Perennial or long duration crops should be followed by seasonal /restorative crops. eg. napier / sugarcane - groundnut /cowpea /green gram.
- Fodder crops should be followed by field or vegetable crops. *e. g*., maize + cowpea-wheat/potato/cabbage/onion.
- Multi-cut crops should be succeeded by the seed crops. *e. g*., green gram/maize.
- Ratoon crops should be followed by deep rooted restorative crops. *e.g.*, sugarcane/jowar-pigeon pea/lucerne/cowpea.
- Deep rooted crops should be succeeded by shallow rooted crops. *e. g*., cotton/ castor/ pigeon pea – potato / lentil /green gram *etc.*
- Deep tillage crops should be followed by zero or minimal tillage crops. *e. g*., potato / radish / sweet potato/sugarcane - black gram/green gram/green manure crops.

Green manures

Green manures are the principal supplementary means of adding organic matter to the soil. The green-manure crop supplies organic matter as well as additional nitrogen, particularly if it is a legume crop, due to its ability to fix atmospheric nitrogen aided by its root nodule bacteria. The green-manure crops also exercise a protective action against erosion and leaching. Green manure is to be incorporated into soil before flowering stage, because these crops are grown for their green leafy material, which is high in nutrients and also protects the soil. Green manures will not break down into the soil quickly, but gradually and add some nutrients to the soil for the next crop. Green manure crops can also be inter-cropped and incorporated which will have dual advantage of managing weeds and soil fertility. Popularly grown green manures are *Sesbania aculeata* (Dhaincha), *Sesbaniarostrata*, sunhemp, etc.

Hedge row /alley cropping

Growing leguminous hedge row species in the bound areas will not only protect the field from outside contaminations, but also serve as a very good source of plant nutrients and feed for cattle. Some important leguminous species suitable for hedge row are *Cajanus cajan*, *Crotolaria tetragona, Desmodium rensonii, Flemingia macrophylla, Indigofera tinctoria* and *Tephrosia candida*, *C. tetragona* can add as high as 50 q fresh leaves / ha /year.

On average, the pruning of N fixing hedgerow species can add 20 - 80; 3 – 14 and 8 - 38 kg N, P and K / ha / year, respectively. Addition of leaf biomass from hedge row species improves the fertility status of the soil and lower the soil acidity remarkably from its initial level. The *C. tetragonoloba* green biomass contains 3.38 per cent N, 0.46 per cent P and 1.51 per cent potassium. The pruning of these species can also be used for mulching, which will help in conserving moisture and on decomposition supply nutrients to the plants.

In alley cropping, arable crops are grown in alleys formed by the trees or shrubs mostly leguminous, to hasten the soil fertility. This ensures use of green leaf manures for the intensity crops during the pruning of the trees. Perennial pigeonpea, *Leucaena leucocephala* is a commonly used species in alley cropping. The height of the tree is maintained by pruning to avoid excessive shading. This type of cropping is also practised in agro-forestry systems and plantation crops for maintaining soil fertility.

3.6.2. Combination of organic nutrient sources

Combining more than one organic source for supplying nutrients to crops has been found to be very effective, as meeting the total nutrient requirement by single source is not possible. For example, rice-wheat system requires around 30 metric tonnes of FYM/year to meet its nutrient demand. This can be very easily managed by adopting strategies of cropping systems involving green manures, legumes and combined application of FYM + vermicompost and neem cake.

This type of management also helps in reducing the insect/disease incidences as incorporation of neem cake in soil has been found to much effective. FYM (partially composed dung, urine, bedding and straw), edible and non-edible oil cakes, enriched composts and effective micro-organisms are some of the combinations which can be used for meeting the nutrient demand of crops. FYM contains approximately 5 - 6 kg of nitrogen, 1.2 - 2.0 kg phosphorus and 5 - 6 kg potash per tonne. Though FYM is the most common organic manure in India, the farmers in general, do not give adequate attention to proper conservation and efficient use of the resource.

For preparing good quality FYM, the use of pit method in regions with less than 1000 mm precipitation and heap method for other regions is recommended. Some of the non-edible oilcakes such as castor and neem cakes possess insecticidal properties also.

Among the edible oil cakes, coconut, groundnut, niger, rapeseed and sesame cakes have higher nutrients (N ranging from 3 to 7.3 per cent; P_2O_5 ranging from 1.5 – 2 per cent and K_2O ranging from 1.2 to 1.8 per cent). In case of non-edible oil cakes such as castor, cotton, karanj, mahua, neem and safflower cakes, neem cake is having higher N (5.2 per cent), while castor and mahua cake is having higher P_2O_5 (1.8 per cent) and K_2O (1.8 per cent) respectively.

Depending upon the nature and quantity of raw material available with the farmer, any one or a combination of composting methods (as described vide see 3.3) can be adopted to make compost within the farm. Effective micro-organism is a consortium culture of different effective microbes commonly occurring in nature. Most important among them are : N_2-fixers, P-solubilizers, photosynthetic microorganisms, lactic acid bacteria, yeasts, plant growth promoting rhizobacteria and various fungi and actinomycetes. In this consortium, each micro-organism has its own beneficial role in nutrient cycling, plant protection and soil health and fertility enrichment. Identified nutrient management packages for various cropping systems are given in Annexure II.

3.6.3. Identified nutrient management packages at different locations

The nutrient management practices for organic food production vary from place to place based on agro-climatic conditions, soil fertility, cropping systems etc.

3.6.4. Insect pest and disease management

In general, the incidence of pests and diseases is comparatively low under organic production system compared to inorganic systems due to several factors, such as application of oil cakes having insecticidal properties, use of green leaf manures like Calotropis and slightly higher content of phenols in plant parts under organic management. Further, organic management also increases the natural enemies (predators) on the farm.

Natural enemies of crop pests and diseases such as Coccinellids, Syrphids, Spiders, Micromus, Chrysopa and Campoletis are found to be higher in number under organic management compared to integrated and inorganic management. Coccinellids, which naturally reduce the hoppers and leaf folders was found to be two to three times higher under organic management in cotton, groundnut, soybean, potato and maize crop fields.

Similarly, spiders which also control the pests are found to be twice higher under organic management compared to inorganic management. The diversity of arthropod population in soil *viz*., Collembola, Dipluran, Pseudoscorpians, Cryptostigmatids and other mite population was also found to be higher under organic management compared to integrated and chemical management.

Table 3.3 Changes in *Coccinelids* and other natural enemy population in various crops under organic and chemical management practices.

Crops	*Coccinelids*		Other natural enemies (*Syrphids, Micromus, Chrysopa, spiders*)		Cumulative per cent reduction of natural enemies / year under chemical management
	Chemical	**Organic**	**Chemical**	**Organic**	
Maize (nos./m)	0.80	2.65	0.50	1.53	68
Ground nut (nos./m)	0.69	2.58	0.76	2.15	69
Soybean (nos./m)	0.35	1.35	-	-	74
Cotton (nos./plant)	1.60	4.15	0.88	2.67	63
Potato (nos./m)	0.30	1.25	0.09	0.30	74

(Source: NPOF)

A popular natural pest repellent paste mixture is seen to be prepared by Tamil Nadu farmers. It contains each 1 kg leaves of *Vitexnigunda*, *Agave cantala* , *Daturametha*, *Calotropis* and neem seeds and is dissolved in 5 litres of cow urine and kept in plastic or earthen ware. After 15 days of fermentation, 100 litres of water is added and the filtrate is sprayed in the field. It has been observed by farmers that most of the insect pests are repelled from the treated area.

Annexure III may be referred to, for some identified pest and disease management packages.

3.6.5. Weed management

Weeds are a major problem under organic management and almost 43 per cent of organic growers opine that low and no cost weed management techniques should be identified for successful practice of organic farming. Slash weeding is to be done between the plants. Weeds under the base of the plants can be cleaned and used as mulch around the plant base. The weeded materials should be applied as mulch in the ground itself. Stale seed beds, hand and mechanical weeding are the other options available for managing weeds under organic management. Further, effective crop rotation, mixed and inter-cropping are also essential for reducing the weeds. Few identified weed management practices for various locations and cropping systems are given in Annexure IV.

The other important practical constraints faced by organic growers are incidence of termites and rats. Some of the Indigenous Technical Knowledge (ITKs) practised for termite management include application of dye prepared from *Noni* (*Morinda citrifolia*) mixed with garlic extract on trees, application of tank silt in sandy wetlands, use of *alotropis* plant material (8-10 kg) soaked in sufficient quantity of water for 24 hr and filtered and poured on termite infested soil and application of sheared human hair obtained from barber's shop, applied on live mounds and along the infested pathways. Another ITK involves collection of maize rachis after removing the grains and placing it in a perforated earthen pot (neck tied with a muslin cloth) and buried in the soil. ITKs used for rat management include pieces of cotton or thermocol dipped in jaggery solution, made into small packets and spread in field / orchard and partly cooked sorghum grains coated with cement or white cement and packed into small packets and spread in the field.

3.7. Crop Productivity and Economics under Organic Management

Analysis of yield recorded at various locations under organic management over inorganic indicate, that many crops respond positively and yield higher under organic systems. Sustainable yield index of basmati rice, rice, cotton, soybean, sunflower, groundnut, lentil, cabbage and french bean are higher under organic management compared to integrated and inorganic management systems. This is however so in systems, where yields have been lower than national averages.

Long-term results of organic management clearly establish that scientific Package of Practices (PoPS) for organic production of crops in cropping systems perspective should be adopted for achieving crop productivity at comparable or even higher level in comparison to chemical farming. Under ICAR-Network Project on Organic Farming (NPOF), location specific package of practices for organic production of crops in cropping systems (42 no's) suitable to 11 states have been developed which can be practised for realising optimum productivity under organic management. Among the pulses, the crops that respond better are green gram, chickpea and cowpea.

Table 3.4 Number of data entries, averages and ranges (per cent) of relative yields between organic over inorganic for selected crops in India (*Source*: NPOF).

Crops	**n[a]**	**Organic over inorganic**		**Crops**	**n[a]**	**Organic over inorganic**	
		Mean	Range			Mean	Range
Basmati rice	67	104	88-121	Okra	10	118	90-142
Rice	52	100	89-122	Chilli	12	109	107-112
Maize	37	110	62-137	Onion	13	107	87-127
Sorghum	17	114	89-132	Garlic	9	104	86-121
Green gram	12	107	96-122	Cauliflower	12	104	90-117
Chickpea	24	100	65-114	Cabbage	5	111	81-142
Soybean	54	104	96-123	Tomato	11	106	83-130
Groundnut	16	103	83-116	Ginger	12	120	108-129

n[a]= the number of yield entries

Cost of production per unit of area is comparable or less under organic agriculture than inorganic management when on-farm organic inputs are used. However, if organic inputs from outside the farm are purchased and utilized, the cost of production increases by about 13 per cent. Therefore, organic agriculture should naturally depend on on-farm generation of inputs including mixed cropping, crop rotation, residue recycling, composting etc.

3.8. Environment saviour

Continuous practice of raising the crops organically has good potential to sequester the C (up to 63 per cent higher C stock in 10 years), higher soil organic carbon (22 per cent increase in 6 years), reduction in energy requirement (by about 10-15 per cent) and increase in water holding capacity (by 15-20 per cent), thereby promoting climate resilience in farming.

3.9. Organic Production - Cluster Approach (case study)

A village (Mynsain) under Umsning Block of Ribhoi District in Meghalaya state has been adopted for disseminating organic production technology in a cluster approach. The village is 20 km away from the institute (ICAR RC for NEH Region, Umiam), having 120 households with an approximate area of 60 ha. Based on interaction with the farmers and elderly people of the village, it is learnt that the village is totally organic and so far no inorganic input has been applied. The sensitization meeting with the villagers including village head (Headman), members of the SHGs and Department of Agriculture was organised to create awareness on adoption of organic farming on scientific basis. A formal Memorandum of Understanding (MOU) between ICAR and the village was signed. The survey (PRA) and farmers training were conducted to initiate the programme. The model has the following components:

- Organic food production: cereals, pulses, oilseeds, vegetables and fruits (using improved seeds and planting materials).
- Food-Feed Crop Production: food for consumption purpose and as feed for livestock.
- Livestock: piggery and dairying. backyard poultry farming.
- Community vermi-composting unit: bio-mass recycling and quality manure production.
- Green manuring and green leaf manuring: generation of organic manure in system.
- Hedge row intercropping: *Tephrosia*, *Crotolaria*, *Indigofera* spp. as fencing, conserve soils and water and supply nutrient rich green leaf manure.
- Planting of multipurpose tree species (MPTS), bamboos etc.: conserving soil, generating additional income as well as for environmental security.
- Development of water harvesting structure: farm ponds and jalkunds.
- Soil conservation measures: terracing, half-moon terracing, vegetative barriers etc.
- Cultivation of fodder crops in degraded lands: to supply green cover and rehabilitate degraded land.
- Organic outlet: near highway for marketing organic produce.
- Capacity building: training and field visits to enhance confidence and capacity of the farmers in organic farming technologies.

Integrated organic farming system improves income and livelihood security in Sikkim- a success story: Shri Nim Tshering Lepcha, resident of Lower Nandok under 26 Naitam-Nandok GPU, East Sikkim had been practicing traditional agriculture in his 2 ha land as the only means of livelihood. Despite hard labour, the farm productivity was low and income was not satisfactory. But the interventions during last three years (2013-16) by Krishi Vigyan Kendra, ICAR Sikkim Centre, Ranipool, East Sikkim have transformed his socio-economic status.

Technological Interventions: Organic farming technological backup by ICAR Research Complex for NEH Region, Sikkim Centre made developmental interventions by providing training, on-field demonstrations and input support. Various inputs/interventions were provided under National Innovations on Climate Resilient Agriculture (NICRA) with the purpose of reorienting his traditional farming into integrated organic farming system (IOFS) to increase the farm income. Major among these are Agri-polythene sheets (250 GSM) for the purpose of making *Jalkund*, micro-rain water harvesting structure; low cost plastic tunnels (transparent UV stabilized sheet of 45 GSM) for sequential vegetable cultivation; garden pea (TSX-10) under zero-till in rice-fallow rotation; cultivation of improved maize line RCM 1-1 and improved rice line RCM-10; backyard poultry production with Vanaraja; and Hybrid Napier cultivation as fodder grass on terrace risers. Scientific management practices of fisheries with Grass carp and Common carp, crossbred Jersey for milk, and large cardamom cultivars *Sawney* and *Varlangey* were also introduced. Vegetables cabbage, cauliflower, broccoli, tomato, coriander, spinach and radish were sequentially cultivated under low cost plastic tunnels. *Jalkund*, a lifesaving water reservoir designed with dimensions of 5 m x 4 m x 1.5 m (capacity of 30,000 l.) proved to be an indispensable tool in meeting the water requirement of crops through gravitational sprinkler irrigation system and encouraged the farmers to opt for diversification of the integrated organic farming system.

This strategy is highly relevant for enhancing the economic options among smaller farms for a labour surplus economy in rural sector for maximization of employment opportunities for uplifting of landless, small and marginal farmers, who constitute about 84 per cent of total farmers. Opportunities for diversification of labour employment have to be created so that growing surplus labour force may be absorbed in the villages this is because the productivity of small farms is not only too low but also farm size is too small to realize the scale of economies.

3.10. Annotation

Organic agriculture is a holistic production management system which promotes and enhances agro-ecosystem health, including bio-diversity, biological cycles and soil biological activity. It emphasizes the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems. This is accomplished by using wherever possible, agronomic, biological, and mechanical methods, as opposed to using synthetic materials, to fulfil any specific function within the system. Interest in organic agricultural methods is growing, especially in areas where the present modern farming system has unleashed many agro-ecological and environmental problems both on and off the farm. Further, consumer awareness of the environmental costs of agriculture is increasing. The concept of food security needs to go beyond mere **'availability' to 'availability of safe food'**. The awareness of environmental quality and health is often promoted by environmental groups, especially in developed countries. The resulting demand for organic products creates the opportunity to sell organic products at premium prices, enabling organic farmers to continue, and often expand. Thus organic agriculture is comparatively free from the complex problems identified with modern agriculture.

It is basically a farming system, devoid of chemical inputs, in which the biological potential of the soil and the underground water resources are conserved and protected from the natural and human induced degradation or depletion by adopting suitable cropping models including agro-forestry and methods of organic replenishment. Besides natural and biological means of pest and disease management, both the soil life and beneficial interactions are also stimulated and sustained. The system as a result achieves self-regulation and stability as well as capacity to produce agricultural outputs at levels which are profitable, enduring over time and consistent with the carrying capacity of the managed agro-ecosystem.

Key Extracts

- The concept of the soil as a living system which must be "fed" in a way that does not restrict activities of beneficial organisms necessary for recycling nutrients and producing humus is central to organic farming.
- Organic farming encourages biological cycles within the farming system, involving micro-organisms, soil flora and fauna, plants and animals and careful mechanical intervention. It maintains the genetic diversity of the production system and its surroundings including the protection of wild life habitats
- Crop production and health in organic farming systems is attained through a combination of structural factors and tactical management components to ensure products of sufficient quality and quantity for human and livestock consumption.
- However, organic farming must be adopted with a caution, so that the nation's food security is not compromised. Since the science of organic farming cannot compete with the already available science & technology of resource-intensive agriculture, areas where use of agro-chemicals is already low and yields are below averages (state & national) may be the first choice.
- At the macro level, an extent of 10 per cent of the nation's cultivated area, that is about 14 million ha. can be the current target for scale up of organic farming.
- NARs needs to take up comprehensive research on organic farming for a long term decision.

Chapter 4
Integrated Farming System

Declining factor productivity, small size of the farms, nutrient mining and multiple nutrient deficiencies, over- exploitation of ground water resources, soil degradation due to intensive tillage practices, and decreased soil organic carbon (SOC) are some of the common concerns over wide range in most parts of the country resulting in stagnation in productivity of the system. Such concerns and problems posed by modern-day agriculture have given birth to new concepts in farming, such as organic farming, natural farming, bio-dynamic agriculture, do-nothing agriculture, eco-farming, etc. The essence of such farming practices simply implies, back to nature to maintain the long run productivity of the soil-plant-animal continuum.

4.1. Introduction

Integrated farming system (IFS) is an entire complex of development, management and allocation of resources as well as decisions and activities, within an operational farm unit, or combinations of units, that result in agricultural production, processing and marketing of the products. IFS is a whole farm management approach that combines the ecological care of a diverse and healthy environment with the economic demands of agriculture to ensure a continuing supply of wholesome, and affordable food. It is a dynamic concept which must have the flexibility to be relevant on any farm, in any country, and it must always be receptive to change and technological advances. Above all, IFS is a practical way forward for agriculture that will benefit the society, not just those who practise it. IFS can be defined as a positive interaction of two or more components of different nature like crops, livestock, fishery, trees etc. within the farm to enhance productivity and profitability in a sustainable and environmentally friendly way. A judicious mix of two or more of these farm enterprises with advanced agronomic management tools may compliment the farm income together with help in recycling the farm residues. The selection of enterprises must be based on the cardinal principles of minimizing the competition and maximizing the complementarity between the enterprises. In general, farming system approach is based on the following objectives:

- Sustainable improvement of farm household systems involving rural communities
- Farm production system improvement through enhanced input efficiency
- Raising the family income
- Satisfying the basic needs of farm families
- Minimising the risk that comes from a single activity

4.2. Farming System Steps

Embedded in general principle is an essential five-step procedure for farming system research and adoption.

Classification: Classification is concerned with the geo-referenced identification of homogenous group of farmers with similar natural and socio-economic characteristics. It forms the basis for the setting of priorities and for targeting of research and extension to particular farm types.

Diagnosis: Diagnosis has to do with identifying the limiting factors, constraints and development opportunities of particular target farm types.

Experimentation and recommendation: Recommendations made from the knowledge, but in field situations which involves experimentation, either at the farm level or at the research station or at both, as a pre-requisite.

Implementation: Implementation commitment is usually found in farming systems programs directly through support to the extension agencies.

Evaluation: Evaluation is an important component and will lead to reappraisal, preferably on GPS location basis.

4.3. Farming Systems Typology

An analysis of benchmark data of 732 number of marginal households across the 30 NARP (National Agricultural Research Project) zones indicates existence of 38 types of farming systems. Of these, 47 per cent of households have adopted integration of crop + dairy, 11 per cent crop + dairy + goatery, 9 per cent crop + dairy + poultry systems and 6 per cent households have only crop component. In terms of number of components integrated by marginal households, 52 per cent households practise only two components while 7 per cent do only one component. The remaining 41 per cent households have components ranging from 3 to 5. There exists scope in the case of 59 per cent of marginal households for integration of allied enterprises for improving the per capita income. Though, the mean holding and family size of marginal households practising upto 2 or more components remains almost same (0.82 ha with 5 no's in 2 component category; and 0.84 ha with 5 no's in > 2 component category), the mean income level is much higher (Rs.1.61 lakh) in case of farms having more than 2 components (e.g., crop + dairy + goatery; crop + dairy + goatery + poultry; crop + dairy + goatery + poultry + fish etc.) in comparison to farms having 2 or less components (Rs.0.57 lakh only in crop alone, dairy alone, crop + dairy, crop + goatery etc.). Diversification of one and two component systems (crop alone, dairy alone, crop + dairy, crop + piggery, crop + poultry, crop + fisheries, crop + horticulture, crop + goatery, dairy + goatery) in the case of 59 per cent marginal household is essential to augment the per capita income.

4.4. Predominant Farming Systems in various Regions

A quick survey conducted as a part of characterization of existing farming systems throughout the country indicated existence of 19 pre-dominant farming systems in India (ICAR, 2013). Crop and livestock system is most dominant (85 per cent) in the country. Based on the contribution of more than 50 per cent of net income from a particular component, the systems are classified as crop, horticulture, livestock or fisheries - dominant system.

Crop dominant farming systems are found in Andhra Pradesh, Bihar, Chhattisgarh, Goa, Haryana, Jammu and Kashmir, Jharkhand, Kerala, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Punjab, Tamil Nadu, Uttar Pradesh, Uttarakhand and north-eastern states.

Livestock dominant systems are present in Rajasthan and parts of Gujarat. States like West Bengal, parts of Odisha and Assam show fisheries as a major source of income in farming systems. Horticulture (fruit) based systems exist in Jammu and Kashmir, Himachal Pradesh, Sikkim and parts of Maharashtra and Uttar Pradesh.

Plantation dominant systems can be promoted in Andaman and Nicobar Islands and Kerala. In some locations (e.g. South 24 Paragnas District of West Bengal State), highly diversified systems also exist, where no single component dominates.

Though, various farming systems exist in the country, integration of input and output within the system is either completely lacking or is at minimal level. There are some missing links in farming systems. For example, cattle is reared but fodder source is limited. Crops and vegetables are cultivated but livestock & water source are lacking. Competition exists within and outside the farm for various by-products generated. Cow dung is the best example as it is required for improving the fertility of soil and also can be used as household fuel. Sustainable farming systems aim at long-term productivity, profitability, recycling of resources and employment generation by harnessing supplementary and complementary relations between different compatible components. The monetary returns under 10 farming systems practised in different parts of the country are given in Fig 4.1. Among the various existing systems in the country, coconut +banana+ cocoa +pineapple + nutmeg (FS9) gives the highest return of Rs 1.27 lakh/annum. The results indicate the importance of fruits and plantation crops in enhancing the net returns of prevailing crop + dairy farming system.

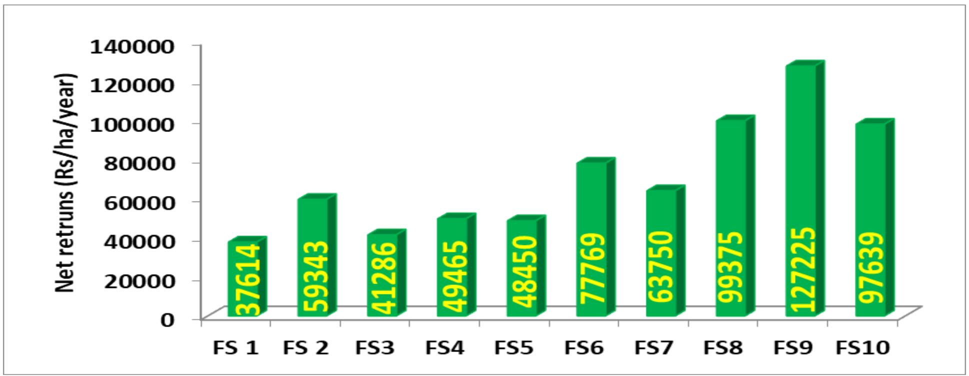


Figure 4.1 Economics of different FS.

FS 1	Crops + dairy	FS6	Crops+dairy+horticulture+poultry+fish
FS 2	Crops +dairy+horticulture	FS7	Rice+fish
FS3	Crops+dairy+poultry	FS8	Coconut +banana
FS4	Crops+dairy+goat	FS9	Coconut+banana+cocoa+pineapple +nutmeg
FS5	Crops+fishery+dairy+poultry	FS10	Crop +dairy+horticulture+apiary+fish

4.5. Significance of IFS Approach

The significance of IFS approach lies in its ability to enhance the system's productivity to meet the demand for food, feed and fuel for ever increasing human and animal population. It also increases the land productivity & profitability and generates additional employment as also income.

Table 4.1 The advantages of IFS approach over arable farming.

SN.	*Advantages*	*How?*
1.	Increased food supply and nutritional security	Horticultural and vegetable crops can provide 2-3 times more calories than cereal crops from the same piece of land. Inclusion of bee keeping, fisheries, sericulture, mushroom cultivation under two or three tier system of integrated farming give substantial additional high energy food without affecting production of foodgrains.
2.	Recycling of farm residues	Proper collection & utilization of livestock excreta (both solid and liquid portion) and litters. This can save up to 50 per cent of NPK requirements. Restoration of soil fertility through organic manuring, bio-mass recycling, use of legumes in cropping system etc. Use of crop residue and plant bio-mass as input for other enterprises, eg. its use in mushroom cultivation, as mulch, substrate in vermi-composting, feed block etc.
3.	Use of marginal and wastelands	Combination of forestry, fishery, poultry, dairying, mushroom and bee keeping can be combined with crop raising and all these activities can be undertaken on marginal & wastelands too.
4.	Increased employment	There is 200 to 400 per cent increase in gainful employment and additional income to farm families, increasing their standard of living.
5.	Multiple use of resources	The appropriate mix of different enterprises and utilization of products within the system results in multiple uses of resources thereby reduction in total cost of inputs leading to higher profitability.
6.	Risk reduction	The effect of climate variability on different crop/animal/fisheries enterprises will be different. So, the farmer will get assured income from one or the other enterprises during extreme years and natural calamities.

The study conducted through on-farm centres reveals, that in case of marginal households having a family size of upto 7, with a mean family size of 5, the effective number of field workable persons are 3 to 4. Even if a bare minimum of 3 persons/household is considered, 1,095 man/woman days (8 hrs in a day) are available per household which is sufficient to practise farming in tiny land holdings. Hence, marginal farms offer greater scope for agricultural diversification, which is labour intensive. It is also reported that because of the integration of different components in one system, an increase in employment generation on yearly basis is seen in Bihar (Kumar et al., 2012) and North East India (Das et al. 2013). The average employment generation increased to 752 man-days/ha/year by integrating crop + fish + duck + goatery compared to other farming system in Bihar. The combining of crops with other enterprises would increase the labour requirement and thus, provide scope to employ more family labours round the year. While comparing traditional agriculture with IFS, lack of gainful employment throughout the year is one of the major challenges. This results in low manpower productivity.

4.6. Farm Diversification under Extreme Weather Situations

The national trends indicate that the non-vegetarian population is increasing over the years and this trend is likely to persist. Therefore, the demand for livestock and fishery products can be expected to increase in future. The traditional system of sole crop or cropping system as prevailing is not sufficient to meet the food and nutritional needs of small households. Diversification is considered to be a good alternative to improve system yield with enhanced profitability. The farming system approach takes into account the components of soil, water, crops, livestock, labour, capital, energy and other resources, with the farm family at the centre managing agricultural and related activities, and is highly location specific in nature. There are two approaches of farming systems, namely, holistic and innovative. The holistic approach deals with improving the productivity of existing components in totality, while innovative approach aims at improving the profitability of existing farming systems. However, a farm family functions within the limitations of its capacity and resources, socio-cultural setting etc. Since small farms are often vulnerable to natural vagaries like flood & drought, farming remains at risk. With increasing population and competing demand from industries and urbanisation, horizontal expansion of agricultural area is not possible. However, vertical expansion of small farms is possible by integrating appropriate farming system components and generating additional space and scope for activities, jobs and income.

4.7. Cropping System as a Tool to Enhance Farmers' income

Crops and ***c***ropping systems with differential behaviour and requirement provide newer challenge as well as opportunity for management to achieve higher productivity of input like water and nutrients. More than 250 double cropping systems are followed throughout the country, amongst which 30 have been identified for irrigated conditions. These systems are rice-wheat, rice-rice, rice-gram, rice-mustard, rice-groundnut, rice-sorghum, pearl millet-gram, pearl millet-mustard, pearl millet-sorghum, cotton-wheat, cotton-gram, cotton-sorghum, cotton-safflower, cotton-groundnut, maize-wheat, maize-gram, sugarcane-wheat, soybean-wheat, sorghum-sorghum, groundnut-wheat, sorghum-groundnut, groundnut-rice, sorghum-wheat, sorghum-gram, pigeon pea-sorghum, groundnut-groundnut, sorghum-rice, groundnut-sorghum and soybean-gram. However, the systems that are considered to be the major contributors to national food basket are: rice (*Oryza sativa* L.)-wheat *(Triticum aestivum* L. emend. Fiori & Paol.) (10.5 million ha), rice-rice (5.9 million ha) and coarse grain (now renamed as nutri-cereals) based systems (10.8 million ha).

Of all these systems, the share of rice and wheat together is the highest, accounting for about 65 per cent of the total foodgrain production. Agronomic research conducted under on- and off-farm situations with these systems brought out a significant change in terms of productivity and profitability besides enhanced input use efficiency. Alternates to the predominant cropping systems that exist, based on replacement and substitution principles developed for 15 agriculturally important agro-climatic regions, have demonstrated significant improvements in the regions. Besides, careful selection of crops in the system, management practices encompassing tillage, residue, nutrient, water and weed play critical role in deciding the overall make up and output of the system. In order to achieve the targeted farmers' income by 2022 through enhancing productivity and profitability of cropping systems, research has to play an important role. Cropping systems will continue to occupy an important position in farming systems management. They will continue to provide sustainable livelihood for about 90 per cent of land holdings, mostly consisting of small and marginal farm house holds.

4.8. Resources for Cropping Systems

Estimates indicate that more than 56 per cent of total foodgrain comes from irrigated ecosystem. The relative contribution of rainfed agriculture is much less (44 per cent), despite accounting for 54 per cent of the net cultivated area. If this trend continues, at least 80 per cent of the incremental food needs required by 2025, may come from irrigated ecosystem. The principal crops having sizeable percentage of area under irrigation in the country are: sugarcane (87.9 per cent), wheat (84.3 per cent), rapeseed and mustard (57.5 per cent), rice (46.8 per cent), tobacco (41.2 per cent), cotton (33.2 per cent), chickpea (21.9 per cent), maize (21.8 per cent) and groundnut (19.2 per cent). Among the states, Punjab ranks first with 94.6 per cent cropped area under irrigation followed by Haryana (76.4 per cent) and Uttar Pradesh (62.3 per cent).

A large diversity of cropping systems exists under rainfed and dry land areas with an overriding practice of inter-cropping. Due to prevailing socio-economic situations (dependency of large population on agriculture, small land-holding size, very high population pressure on land resource etc.), improving household food security will be of critical importance for the millions of farmers of India. They constitute 56.15 million marginal (<1.0 hectare), 17.92 million small (1.0-2.0 hectare) and 13.25 million semi-medium (2.0-4.0 hectare) farm holdings, together accounting for 90 per cent of the total of 97.15 million operational holdings. An important consequence of this is the predominance of subsistence farming, and not commercial. One of the typical characteristics of subsistence farming is, that most of the farmers resort to cultivating a number of crops on their farm holdings, primarily to fulfil their household needs and follow the practice of rotating a particular crop combination over a period of 3-4 years inter-changeably on different farm fields.

4.9. Multiple Uses of Water

The IFS involving location-specific enterprises can promote multiple uses of water at farm level. Integrating fish production and animal husbandry with water management strategy offers a great potential for increasing the water use efficiency and additional production of protein without much water consumption. Synergistic interactions between fishery and agricultural sectors need to be explored by promoting recycling of livestock or farming wastes and nutrients, as also optimal use of scarce land and water resources. Farming enterprises include crop, livestock, poultry, fish, tree crops, plantation crops, forestry, sericulture *etc.* A combination of one or more enterprises with cropping, when carefully chosen, planned and executed, can yield greater dividends than single enterprise, especially in case of small and marginal farmers. Farm as a unit is to be considered and planned for effective integration of enterprises with crop production activity. Multiple uses of water also substantially enhances water productivity as against one or two commodity based farming. The integration of farm enterprises depends on many factors such as:

- Soil and climatic features of the selected area
- Availability of resources, land, labour, capital and skills.
- Present level of utilization of resources
- Returns from existing farming system
- Economics of proposed integrated farming system
- Managerial skill of the farmer

The paradigm of sustainability in IFS refers to satisfying the needs of the present generation without compromising the resource base of future generations. The integration of farm enterprises is often suggested as the means for rapid and comprehensive development of agriculture in India. Having achieved green and white revolutions through various technological and institutional transformations, the country is now said to be poised for blue revolution involving substantial increase in fish output.

4.10. Farming Systems Typology and Quantitative Analysis Tools

A farm is conceived as a management unit consisting of a large array of inter-related components of various types. The planning of mixed farming systems with an array of crops, various animal types and a diverse range of other resources is complicated, since it involves many management decisions on resource allocation (Russelle et al., 2007). Traditionally, farmers depend on traditional methods, such as, instinct and experience, and comparisons with neighbours in order to make decisions about which commodities to produce and in what quantities. This does not guarantee optimal cropping patterns (Alsheikh and Ahmed, 2002) as these choices and their resulting outcomes are subject to a large range of objectives and constraints. There exists a chain of interactions among the components within the farming systems, and it becomes difficult to deal with such inter-linking complex systems manually. This problem could be overcome by construction and application of suitable whole farm models. Optimization techniques, such as linear programming, fuzzy linear programming, etc. are useful tools for efficient resource allocation under various constraints. Model-based support can be useful in various hierarchically structured planning windows.

Farming system typology involves grouping farming systems in terms of their resources and livelihood activities, as well as agricultural management practices, which can be used for planning agricultural interventions. Farming system typologies can be used to explore and assess the possible impact of climate shocks and alternative technological interventions on food security of farm households (Santiago et al., 2017).

Recently, various tools have been developed and applied for IFS analysis (Andrieu and Nogueira, 2010; Le Gal et al., 2010; Del Prado et al., 2011) and for the exploration of strategic improvements in farming systems (Groot et al., 2007; Tittonell et al., 2007a, 2007b; Vayssières et al., 2010). Groot et al., (2012) described about Farm DESIGN tool, which supports evaluation and re-design of mixed farming systems in tactical planning processes and supported the analysis of problems in the original farm configuration and indicated avenues for adjustments of the configuration to improve farm performance in terms of various objectives. Relatively small modifications in the farm configuration through optimization may result in considerable improvement of farm performance.

4.11. Specific Strategies for Sustainability of Integrated Farming Systems

4.11.1. Integrated farming systems for different zones

The concepts associated with IFS are practised by numerous farmers across the globe. A common characteristic of these systems is, that they invariably have a combination of crop and livestock enterprises and in some cases may include combinations of aquaculture and trees. Water storage structure will be central to all the farming activities. Suggested IFS for different zones in India (Jayanthi *et al*. 2002) are given below:

High altitude cold desert: Pastures with forestry, sheep, goats, rabbits, and yak along with limited crops like millets, wheat, barley, vegetables and fodders.

Arid and desert regions: Animal husbandry with camels, sheep and goat with moderate crop component involving pearl millet, wheat, pulses, oil seeds and fodders.

Western and Central Himalayas: Emphasis on horticultural crops with crops like maize, wheat, rice, pulses and fodders on terraces, pastures with forestry, poultry, sheep, goats, rabbits, and yak (at altitudes above 2,500 m amsl).

Eastern Himalayas: Horticultural crops with crops like maize, wheat, rice, pulses and pasture on terraces, pastures with forestry, sheep, goats, rabbits, yak and cold water fisheries at altitudes above 2000 m amsl. Maize, rice, french bean, ricebean, piggery, poultry, fishery and cole crops above 1000 m amsl. Rice, pulses, dairying, fish culture, vegetables in case of less than 1,000 m amsl.

Indo-Gangetic Plains: Intensive crop husbandry involving rice, maize, wheat, mustard and pulses and dairy.

Central and southern highlands: Crops such as millets, pulses, and cotton along with dairy cattle, sheep, goat and poultry.

Western Ghats: Plantation crops, rice and pulses as also livestock components including cattle, sheep and goats.

Delta and coastal plains: Rice and pulse crops along with fish and poultry.

Science based IFS models have been established in all the 15 agro-climatic regions through AICRP on IFS network covering 23 states and 2 UTs. All the farming system models offer scope to improve the income in a sustainable way. The details of the state-specific farming system models are presented in Table 4.2.

Table 4.2 Profitable and sustainable integrated farming System models

District (State)	District	Prevailing Farming System (PFS)	Suggested IFS Model	Increase in net income over PFS (per cent)	Sustainable value index (SVI)
Andhra Pradesh	Medak	Crop + Dairy	Crop + Dairy + Horticulture + Goat/poultry	135	0.33
Assam	Jorhat	Crop+ Dairy	Crop + Dairy + Horticulture + Fishery + Apiary	669	0.24
Bihar	Sabour	Crop + Dairy	Crop + Dairy + Horticulture + Fishery + Goat + Duck	296	0.47
	Patna	Crop + Dairy	Crop + Dairy + Horticulture + Fishery + Goat/poultry/duckery + Mushroom	184	0.76
Chhatisgarh	Raipur	Crop + dairy	Crop + Dairy + Horticulture + Fishery + Poultry + Mushroom	134	0.21
Goa	Goa	Crops + dairy	Crop + Dairy + Horticulture + Fishery + Mushroom	643	-*
Gujarat	S.K.Nagar	Crop + Dairy	Crop + Dairy + Horticulture	354	0.46
Haryana	Hisar	Crop + Dairy	Crop + Dairy + Horticulture	257	0.28
Himachal Pradesh	Palampur	Livestock + cereals based	Crop + Dairy + Horticulture +	306	0.48
Jammu and Kashmir	Chhata	Crop+Dairy	Crop + Dairy + Horticulture + Fishery + Poultry + Agroforestry + Apiary	254	0.69
Jharkhand	Ranchi	Crop + dairy/Goat + Pig	Crop + Dairy + Horticulture + Fishery + Mushroom	298	0.19
Karnataka	Siruguppa	Crop + Dairy	Crop + Dairy + Horticulture + Fishery + Goat	118	0.53
Maharashtra	Akola	Crop + Goat + Horti. + Poultry	Crop + Dairy + Horticulture + Goat/poultry	216	-
	Rahuri	Crop + Dairy	Crop + Dairy + Horticulture + Poultry	226	-
	Karjat	Crop + Livestock	Crop + Dairy + Horticulture + Goat/poultry	26	0.70
Orissa	Bhubnesw	Crop +	Crop + Dairy + Horticulture	265	0.30

District (State)	District	Prevailing Farming System (PFS)	Suggested IFS Model	Increase in net income over PFS (per cent)	Sustainable value index (SVI)
	ar	Dairy +Hort. (vegetables)	+ Apiary + Fishery + Poultry/ duckery/ + Agroforestry + Mushrrom		
Punjab	Ludhiana	Crop + Dairy	Crop + Dairy + Horticulture + Fishery + Agroforestry + Apiary	144	0.46
Rajasthan	Durgapura	Crop + Dairy	Crop + Dairy + Horticulture + Goat/poultry	78	0.73
Tamil Nadu	Coimbatore	Crop + Dairy	Crop + Dairy + Horticulture + Goatery	88	0.90
	Thanjavur	Crop + Dairy + Horticulture	Crop + Dairy + Horticulture + Fishery + Poultry	222	0.77
Uttar Pradesh	Meerut	Crop + Dairy	Crop + Dairy + Horticulture + Mushroom + Biogas	373	-
	Varanasi	Crop + Dairy	Crop + Dairy + Horticulture + Fishery + Poultry + Mushroom	431	-
Uttarakhand	US Nagar	Crop + Dairy + Tree plantations	Crop + Dairy + Horticulture + Agroforestry	92	-
West Bengal	Nadia	Crop + Dairy + Vegt./Goat /Poult.	Crop + Dairy + Horticulture + Fishery	109	-
Meghalaya	Ri-bhoi	Jhum/ ginger (sloping land)	Crop + dairy + fodder + spices	184	-
			Crop + fruit + vegetables + poultry + piggery	174	-
		Upland crops and fish (Valley land, no-integration)	Crop–fish–pig–bamboo–MPTs–fruit trees–hedge rows	215	-

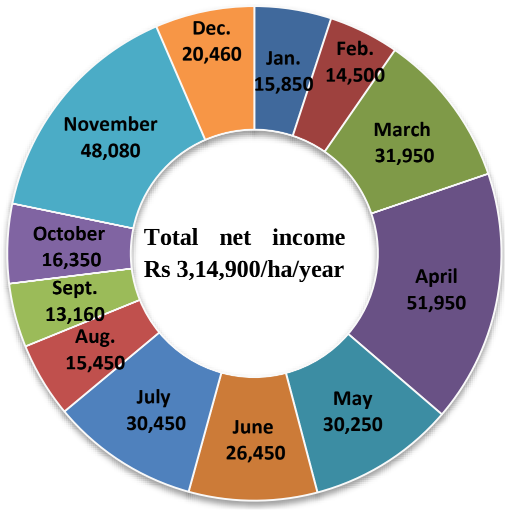
-*Sufficient data not available for calculation of SVI

4.11.2. Family farming model for nutrition and round the year income – A case study of Bihar

A one hectare area with 5 member family farming model comprising diversified cropping systems (0.78 ha) + horticulture (0.14 ha)+ dairy (2 cows) + goat (11 no's) + fish (0.1 ha) + ducks (25 no's) + boundary plantation (subabul, 225 plants & Moringa, 50 plants) developed for South Bihar Alluvial Plain Zone (BI-3) in Middle Gangetic Plains region

Crop + horticulture + dairy + goat +fish + duck + boundary plantation family farming model at AICRP on IFS centre, Sabour (Bihar) provides round the year income which ranges between Rs 13,160 (September) to 51,950 (April)/ha/month.

The diversified cropping systems [rice - wheat – green gram (grain + residue incorporation), rice - maize + potato - cowpea (fodder), rice - mustard - maize (grain) + cowpea (fodder), sorghum + rice bean – berseem / oat- maize + cowpea (fodder) and seasonal vegetables (brinjal, tomato, cauliflower, cabbage, vegetable pea, okra, lettuce) grown in 0.78 ha area could meet the full family requirement of 1100, 95, 125, 185 & 640 kg of cereals, pulses, oilseeds, fruits (guava & papaya) and vegetables and livestock requirement of 29.5 & 6.6 t of green and dry fodder per annum, respectively.



The model could also meet the milk, egg and fish requirement of 550 litres, 900 no's and 120 kg, respectively. Besides meeting the family and livestock requirements, the model produced marketable surpluses of 4810, 986 and 35 kg of cereals, vegetables and fruits respectively; and also marketable surpluses of milk, egg and fish at 4243 litres, 950 numbers & 124 kg, respectively which resulted in round the year income. The model also ensured fuel wood availability of 4 t/year for the family and could add 4 t of enriched vermi-compost and 2.3 t of manure to improve the soil health.

The value of recycled products and by-products from the model worked out to Rs 1.29 lakh which reduced the total cost (Rs 3.1 lakh) of the model by 42 per cent. The family labour (730 man days) contributed to save 37 per cent of cost. Hence, only 21 per cent (Rs 0.68 lakh) of total cost is involved in the form of inputs purchased from the market. A total net return of Rs 3.14 lakh was realised which is 3.2 times higher than the existing pre-dominant crop + dairy system of the zone. The Cost: Benefit ratio of the model was impressive at 4.6.

Round the year net income (Rs/ha) for the family was: crop (0.78 ha) + horticulture (0.14 ha) + dairy (2 cows) + goat (11 no's) + fish (0.1 ha) + ducks (25 no's) + boundary plantation (subabul and moringa) farming system model at Sabour (Bihar).

The monetary input ration output from some of the intensive IFS models established in north eastern hill region. The total output/input ratio was highest (1.76) in crop–fish–dairy–MPTs–fruit trees–hedge rows–vermiculture–liquid manure–broom grass followed by broiler chicken–crop–fish–duck–horticulture–nitrogen fixing hedge row (1.58). The monetary output / input ratio could further increase if family labor is engaged for adopting IIFS (for detailed report refer to Bhatt and Bujarbaruah 2005).

Table 4.3 Input and output ratios from some intensive IFS models in Umiam, Meghalaya

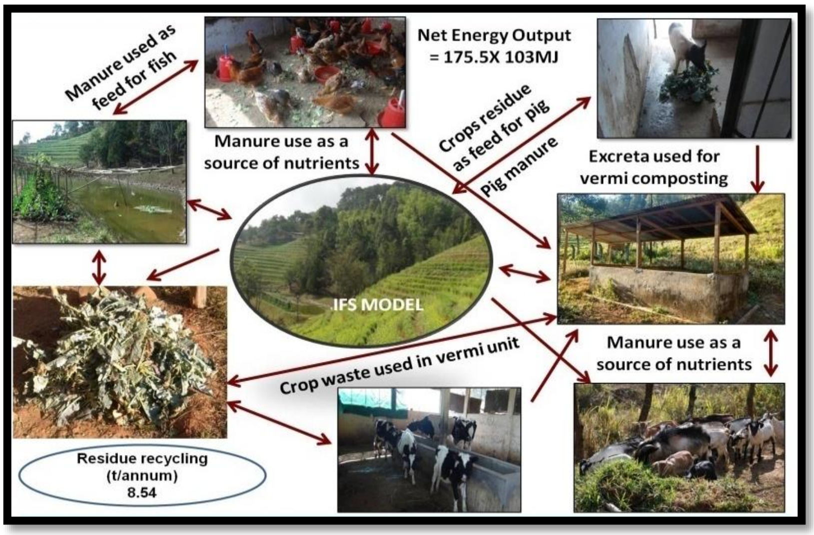
IIFS models	Input	Output	Output/ input ratio
Broiler chicken – crop – fish – duck – horticulture – nitrogen fixing hedge row	1,05,722	1,67,331	1.58
Crop – fish – poultry – multipurpose trees	60,137	90,625	1.51
Crop – fish – goat – MPTs – hedge row	59,442	91,880	1.55
Crop – fish – pig – bamboo – MPTs – fruit trees – hedge rows	77,273	1,09,887	1.42
Crop – fish – dairy – MPTs – fruit trees – hedge rows – vermiculture – liquid manure – broom	1,70,120	2,98,735	1.76
Upland crops, and fish farming without integration (control)	31,773	34894	1.09

Source: Singh et al. (2014)

4.11.3. Bio-resource flow in IFS

Adoption of conservation agriculture principles, inclusion of green manure crops, legumes and pulses, cover crops, composts, vermicomposts, hedgerow plants, liquid manure, FYM, mulching, use of pond silts to crops etc. are some components of efficient bio-resource recycling.

Figure 4.2 Bio-resource flow in IFS



(Source: Farming System Research Project, ICAR Complex, Umiam, 2017)

Bio-resource flow of a suitable IFS model for sloping lands of eastern Himalayan region is presented in Fig 4.2. A viable IFS model should promote maximum on-farm recycling of bio-resources with minimal dependence on external resources. While selecting components of IFS for a particular region, emphasis should be on bio-resource flow, and missing link if any should be plugged. For example, food-feed crops should be integral part of any IFS model to reduce man-animal conflict.

Also, a component of nutrient cycling and demand of various nutrients should be kept in mind while designing the model. Each and every enterprise of the model should be linked with at least one component, so that the farm demand is met with the model to a great extent. In an organic IFS model in Umiam, Meghalaya (valley land), it has been observed, that at least 92 per cent N, 88 per cent P and almost cent percent K requirement of the model is met with effective on-farm resource recycling (Das et al., 2016).

4.11.4. Farmer participatory research

Innovations by way of introducing new crops, livestock species and product or processing techniques in marginal households could enhance productivity and profitability of farm households. Farmer participation based research is a good way of benchmarking the improvements over the existing systems in practice. (See Annexure V)

- cropping system diversification (based on most efficient cropping systems keeping in view of the farmers resources, perception, willingness, market and requirement other components in the system);
- livestock diversification [(mineral mixture + de-worming+ round the year fodder supply for existing components) + introduction of location specific low cost livestock components *viz*., backyard poultry farming, duckery, piggery, goat *etc.*)];
- product diversification (preparation of mineral mixture/value addition of market surplus products/Kitchen /roof gardening); and capacity building (training of farm households on farming systems including post-harvest and value addition and assessing its impact)

In a study carried out in different states, the following status was seen to exist:

- The number of farming systems in different districts of the country varied from 1 to 8. Presence of maximum of 8 (eight) farming systems was observed in South 24 Paragnas district (West Bengal) and minimum of one farming systems in 5 districts, namely, Samba (Jammu & Kashmir), Amritsar (Punjab), Palghar and Pune (Maharashtra) and Gadag (Karnataka).
- Existence of 6 (six) farming systems at Panchmahal (Gujarat) and 5 (five) farming systems at Kabirdham (Chhatisgarh), Dindori (Madhya Pradesh), Srikakulam (Andhra Pradesh), Warangal (Telangana), Kendrapara (Odisha) districts were observed.

- Field crops + dairy was found to be the common farming system at all locations in marginal households and it is the dominant system practiced in 17 districts based on number of households adopting the system.
- Field crops + dairy + poultry is found to be the dominant farming system in Udaipur (Rajasthan), Warangal (Telangana), Srikakulam (Andhra Pradesh) and Sivagangai (Tamil Nadu). Similarly, field crops + dairy + goat were found to be pre-dominant system in Purnea (Bihar) district. At Kanpur Dehat (Uttar Pradesh), both field crops + dairy and filed crops + dairy + goat were found as dominant systems. In case of South 24 Paragnas (West Bengal) and Panchmahal (Gujarat), highly diversified system was noticed.
- Field crop alone was found to be dominant practice adopted by large number of households in Kabirdham (Chhatisgarh) and Aurangabad (Maharashtra) districts.
- Across the locations and farming systems, improvement of existing farming systems with diversification approach in cropping system, livestock, product diversification and capacity building module resulted in considerable improvement in production (up to 2 times), marketable surplus (1-2 time), reduction in cost (20per cent) due to recycling, returns (2 times) and profit (cash flow for family by 1-2 times).
- Based on statistical analysis, best performing IFS has been identified for each district which needs to be up-scaled along with all possible interventions and diversification approach for improving the livelihood of marginal farm households.

4.11.5. Identification of high productive cropping systems

Widespread occurrence of second-generation problems, such as over-mining of soil nutrients, decline in factor productivity, reduction in profitability, lowering of groundwater tables and building up of pests including weeds, diseases and insects has been reported during post-green revolution era in most of the intensively cultivated, high-productivity, cereal based production systems. These are now threatening food security and ecosystem sustainability.

Studies carried out under AICRP on Cropping System have resulted in identification of appropriate duration of varieties for some popular crop sequences for different regions of the country. Considering the specific needs of different regions, concerted efforts have been made to design new alternative cropping system. Several new cropping systems are, emerging in selected regions due to inclusion of high value crops and their high yielding and disease resistant varieties in the cropping sequences. These alternative improved cropping systems are found to be more remunerative than the existing cropping systems for that particular area. Location-wise existing as well as improved cropping systems are enlisted in Annexure - VI.

4.12. Sustainability of IFS Models

The following features should become integral to the farming systems, if they are to become sustainable.

- Model should be self-input generating, seeking minimum requirement of external resources from the market.
- Model should be able to generate year round employment and income-perennial yield of income in contrast to seasonal nature of income.
- Waste of one component should be wealth for another component, implying that complementarity should exist between/among the various components.
- Model should be energy efficient, economically viable and socially acceptable.
- Rationality should be maintained among economic, ecological and social dimensions of IFS models.
- Model should be capable of sustaining the farm family's nutritional needs as recommended by Indian Council of Medical Research (ICMR). While designing the IFS Models, ecosystem services should be take into consideration. The model should effectively reduce GHG emission and check soil and nutrients erosions.
- IFS model is more likely to sustain, when it is built over traditional systems, where due importance is given to indigenous crops and bio-diversity.

4.13. Annotation

It is a resource management strategy deployed to achieve economic and sustained production to meet diverse requirement of a farm household, while preserving resource base and maintaining a high level of environmental quality. In farming system, the farm is viewed in a holistic manner.

Farming enterprises include crops, dairying, poultry, fishery, sericulture, piggery, apiary, tree crops etc. A combination of one or more enterprises with cropping when carefully chosen, planned and executed, yields greater dividends than a single enterprise, especially in case of small and marginal farmers. Farm as a unit is to be considered and planned for effective integration of the enterprises with crop production activity, such that the end-products and wastes of one enterprise are utilized effectively as inputs in other enterprise.

Sustainability is the principle objective of the farming system, where production process is optimized through efficient utilization of inputs without infringing on the quality of environment with which it interacts on one hand, and attempts to meet the national goals on the other. The concept has an undefined time dimension.

The magnitude of time dimension depends upon one's objectives, being shorter for economic gains and longer for concerns pertaining to environment, soil productivity and land degradation. Farming system provides an opportunity to increase economic yield per unit area per unit time by virtue of intensification of crop and allied enterprises.

Key Extracts

- The farming system as a whole provides an opportunity to make use of produce/waste material of one enterprise as an input in another enterprise at low/no cost. Thus, by reducing the cost of production the profitability and benefit cost ratio works out to be high.
- In farming system, diverse enterprises are involved and they produce different sources of nutrition namely proteins, carbohydrates, fats & minerals etc. form the same unit of land, which helps in solving the malnutrition problem prevalent among the marginal and sub-marginal farming households.
- The very nature of farming system is to make use of or conserve the by product/waste product of one component as input in another component and use of bio-control measures for pest & disease control. These eco-friendly practices bring down the application of huge quantities of fertilizers, pesticides and herbicides, which pollute the soil, water and environment to an alarming level. Whereas IFS will greatly reduces environmental pollution.
- An IFS provides good scope for resource utilization in different components leading to greater input use efficiency and benefit- cost ratio.

Chapter 5

Good Agricultural Practices

As high quality and healthy foods are gaining currency, consumers have concerns about the control of food production and hence demand more information along the food chain. Good Agricultural Practice (GAP) is based on the principles of risk prevention, risk analysis, sustainable agriculture and Integrated Crop Management (ICM) to continuously improve farming systems. GAP is of utmost importance in protecting consumer health.

5.1. Introduction

The Food and Agricultural Organization (FAO) of the United Nations uses Good Agricultural Practice (GAP) as a collection of principles to apply for on-farm production and post-production processes, resulting in safe and healthy food and non-food agricultural products, while taking into account economic, social and environmental sustainability. These four 'pillars' of GAP (economic viability, environmental sustainability, social acceptability, and food safety & quality) are included in most private and public sector standards, but the scope which they actually cover varies widely. The concept of Good Agricultural Practices (GAPs) has evolved in recent years in the context of a rapidly changing and globalizing food economy, and as a result of the concerns and commitments of a wide range of stakeholders about food production and security, food safety and quality, and the environmental sustainability of agriculture. A broadly accepted approach using GAP principles, generic indicators and practices will help guide the debate on national policies, actions and preparation of strategies, so as to ensure that all stakeholders benefit from the application of GAP in the food chain. The implementation of GAP should therefore contribute to Sustainable Agriculture and Rural Development (SARD). Its broad objectives are:

- Ensuring safety and quality of produce in the food chain.
- Capturing new market advantages by modifying supply chain governance.
- Improving natural resources use, workers' health and working conditions; creating new market opportunities for farmers and exporters in developing countries.

5.2. Key Elements of GAP

Some key elements are as follows:

- Prevention of problems *before* they occur
- Risk assessment
- Commitment to food safety at all levels
- Communication through the production chain
- Mandatory employee education program at the operational level
- Field and equipment sanitation
- Integrated pest management
- Oversight and enforcement

- Verification through independent, third-party audits

5.3. Potential Benefits of GAP

Some identified positive outcomes are listed below:

- Appropriate adoption and monitoring of GAP helps to improve the safety and quality of food and other agricultural products.
- It may help to reduce the risk of non-compliance with national and international regulations, standards and guidelines and the International Plant Protection Convention (IPPC) in relation to permitted pesticides, maximum levels of contaminants in food and non-food agricultural products, as well as other chemical, micro-biological and physical contamination hazards.
- Adoption of GAP helps to promote sustainable agriculture and contribute to meeting national and international environment and social development objectives.

5.4. Challenges related to GAP

Some of the challenges are as follows:

- In some cases, GAP implementation and especially record keeping and certification increases production costs. In this respect, lack of harmonization between existing GAP-related schemes and availability of affordable certification systems has often led to increased confusion and certification costs for farmers and exporters.
- There is a high risk that small scale farmers will not be able to seize export market opportunities unless they are adequately informed, technically prepared and organized to meet this new challenge, with governments and public agencies playing a facilitating role.
- Compliance with GAP standards does not always foster all the environmental and social benefits, as claimed.
- Need for creating awareness about 'win-win' practices that will bring about improvements in yield and production efficiencies, as well as environment and health and safety of workers. One such approach is Integrated Production and Pest Management (IPPM).

5.5. Good Agricultural Practices for selected Agricultural Components

5.3.1. Soil

- Appropriate soil management aims to maintain and improve soil productivity by improving the availability and plant uptake of water and nutrients through enhancing soil biological activity, replenishing soil organic matter and soil moisture, and minimizing losses of soil, nutrients, and agro-chemicals through erosion, run-off and leaching into surface or ground water.
- Good practices related to soil include maintaining or improving soil organic matter through the use of soil carbon-build up by appropriate crop rotations, manure

application, pasture management and other land use practices, rational mechanical and/or conservation tillage practices; maintaining soil cover to provide a conducive habitat for soil biota, minimizing erosion losses by wind and/or water; and application of organic and mineral fertilizers and other agro-chemicals in amounts and timing and by methods appropriate to agronomic, environmental and human health requirements.

5.3.2. Water

- Agriculture carries a high responsibility for the management of water resources in quantitative and qualitative terms, since it is using more than 80 per cent of the utilisable water in the country. Careful management of water resources and efficient use of water for rainfed crop and pasture production, for irrigation where applicable, and for livestock, are criteria for GAP. Efficient irrigation technologies, as also new generation technologies like sensors and management will minimize waste and will avoid excessive leaching and salinization.
- Good practices related to water will include those that maximize water infiltration and minimize unproductive efflux of surface waters from watersheds; manage ground and soil water by proper use, or avoidance of drainage where required; improve soil structure and increase soil organic matter content; apply production inputs, including waste or recycled products of organic, inorganic and synthetic nature by practices that avoid contamination of water resources; adopt techniques to monitor crop and soil water status, accurately schedule irrigation, and prevent soil salinization by adopting water-saving measures.

5.3.3. Crop and fodder production

- Crop and fodder production involves the selection of annual and perennial crops, their cultivars and varieties, to meet local consumer and market needs according to their suitability to the site and their role within the crop rotation for the management of soil fertility, pests and diseases, and their response to available inputs. Perennial crops are used to provide long-term production options and opportunities for inter-cropping. Annual crops are grown in sequences, including those with pasture, to maximize the biological benefits of interactions between species and to maintain productivity. Harvesting of all crop and animal products removes their nutrient content from the site and must ultimately be replaced to maintain long-term productivity.
- Good practices related to crop and fodder production will include those that select cultivars and varieties on an understanding of their characteristics, including response to sowing or planting time, productivity, quality, market acceptability and nutritional value, disease and stress resistance, edaphic and climatic adaptability, and response to fertilizers and agrochemicals; devise crop sequences to optimize use of labour and equipment and maximize the biological benefits of weed control by competition, mechanical, biological and herbicide options, provision of non-host crops to minimize disease and, where appropriate, inclusion of legumes to provide a biological source of nitrogen; apply fertilizers, organic and inorganic, in a balanced fashion, with

appropriate methods and equipment and at adequate intervals to replace nutrients extracted by harvest or lost during production. The safety regulations and established safety standards for the operation of equipment and machinery for crop and fodder production are needed for GAP.

- Crop rotation is the best management practice for agricultural and horticultural crops. It will address loss of organic matter, disease, weed and insect pressures, soil nutrition, compaction and erosion.

5.3.4. Crop protection

- Maintenance of crop health is essential for successful farming with respect to both yield and quality of produce. This requires long-term strategies to manage risks by the use of disease- and pest-resistant crops, crop and pasture rotations, disease breaks for susceptible crops, and the judicious use of agro-chemicals to control weeds, pests, and diseases following the principles of Integrated Pest Management.
- Good practices related to crop protection will include those that use resistant cultivars and varieties, crop sequences, associations, and cultural practices that maximize biological prevention of pests and diseases; maintain regular and quantitative assessment of the balance status between pests and diseases and beneficial organisms of all crops; adopt organic control practices where and when applicable; apply pest and disease forecasting techniques where available; determine interventions following consideration of all possible methods and their short- and long-term effects on farm productivity and environmental implications in order to minimize the use of agro-chemicals, in particular to promote integrated pest management (IPM). It is to ensure that agro-chemicals are only applied by specially trained and knowledgeable persons and accurate records of agrochemical use is maintained.

5.3.5. Animal production

- Livestock require adequate space, feed, and water for their welfare and productivity. Stocking rates must be adjusted and supplements provided as needed to livestock grazing pasture or rangeland. Chemical and biological contaminants in livestock feeds are avoided to maintain animal health and/or to prevent their entry into the food chain.
- Good practices related to animal production will include those that site livestock units appropriately to avoid negative effects on the landscape, environment, and animal welfare; avoid biological, chemical, and physical contamination of pasture, feed, water, and the atmosphere; frequently monitor the condition of stock and adjust stocking rates, The minimum use of the non-therapeutic use of antibiotics; integrate livestock and agriculture to avoid problems of waste removal, nutrient loss, and greenhouse gas emissions by efficient recycling of nutrients are important GAP.

5.3.6. Animal health and welfare

- Successful animal production requires attention to animal health, that is maintained by proper management and housing, by preventive treatments such as vaccination, and by regular inspection, identification, and treatment of ailments, using veterinary advice as required.

- Good practices related to animal health and welfare will include those that minimize risk of infection and disease by good pasture management, safe feeding, appropriate stocking rates and good housing conditions; keep livestock, buildings and feed facilities clean and provide adequate, clean bedding where livestock is housed; ensure staff are properly trained in the handling and treatment of animals; seek appropriate veterinary advice to avoid disease and health problems; ensure good hygiene standards in housing by proper cleansing and disinfection; treat sick or injured animals promptly in consultation with a veterinarian.

5.3.7. Harvest and on-farm processing and storage

- Product quality also depends upon implementation of acceptable protocols for harvesting, storage, and where appropriate, processing of farm products. Harvesting must conform to regulations relating to pre-harvest intervals for agro-chemicals and withholding periods for veterinary medicines. Food produce should be stored under appropriate conditions of temperature and humidity in space designed and reserved for that purpose. Operations involving animals, such as shearing and slaughter, must adhere to animal health and welfare standards.
- Good practices related to harvest and on-farm processing and storage will include those that harvest food products following relevant pre-harvest intervals and withholding periods; provide for clean and safe handling for on-farm processing of products. For washing, use recommended detergents and clean water; store food products under hygienic and appropriate environmental conditions; pack food produce for transport from the farm in clean and appropriate containers.

5.3.8. Energy and waste management

- Energy and waste management are also components of sustainable production systems. Farms require fuel to drive machinery for cultural operations, for processing, and for transport. The objective is to perform operations in a timely fashion, reduce the drudgery of human labour, improve efficiency, diversify energy sources, and reduce energy use.
- Good practices related to energy and waste management will include those that establish input-output plans for farm energy, nutrients, and agro-chemicals to ensure efficient use and safe disposal; adopt energy saving practices in building design, machinery size, maintenance, and use; investigate alternative energy sources to fossil fuels (wind, solar, biofuels) and adopt them where feasible; recycle organic wastes and inorganic materials.

5.3.9. Human welfare, health and safety

- Human welfare, health and safety are additional components of sustainability. Farming must be economically viable to be sustainable. The social and economic welfare of farmers, farm workers, and their communities depends upon it. Health and safety are also important concerns for those involved in farming operations.

- Good practices related to human welfare, health and safety will include those that direct all farming practices to achieve an optimum balance between economic, environmental, and social goals; provide adequate household income and food security; adhere to safe work procedures with acceptable working hours and allowance for rest periods; instruct workers in the safe and efficient use of tools and machinery; pay reasonable wages and not exploit workers, especially women and children; and purchase inputs and other services from local merchants if possible.

5.3.10. Wildlife and landscape

- Agricultural land accommodates a diverse range of animals, birds, insects, and plants. Much public concern about modern farming is directed at the loss of some of these species from the countryside because their habitats have been destroyed. The challenge is to manage and enhance wildlife habitats while keeping the farm business economically viable.
- Good practices related to wildlife and landscapes will include those that identify and conserve wildlife habitats and landscape features, such as isolated trees, on the farm; create, as far as possible, a diverse cropping pattern on the farm; minimize the impact of operations such as tillage and agro-chemical use on wildlife; manage field margins to reduce noxious weeds and to encourage a diverse flora and fauna with beneficial species; manage water courses and wetlands to encourage wildlife and to prevent pollution; and monitor those species of plants and animals whose presence on the farm is evidence of good environmental practice.

5.4. GAP - Resource Use Efficiency and Sustainability

Some of the practices for promoting resource use efficiency and sustainability of agriculture are discussed below.

5.4.1. Zero tillage

A holistic approach is needed to tackle second-generation problems and to improve the sustainability of this cropping system. However, interventions in the form of new resource conservation technologies (RCTs) must include the components of profitability, value addition, efficiency and farmers' participatory approach for their large-scale acceptance. Introduction of zero-tillage in wheat in Haryana, and thereafter, its popularization in the adjoining states during the last eight years is a unique example in this context. The new benefits of zero-tillage technique in wheat realized at farmers' fields have also been positive. For the past eight years, the evolution and acceleration of zero-tillage in Haryana has been one of the few big ideas in introducing conservation agriculture.

Farmers in the Indo- Gangetic Plains have rediscovered the virtue of technologies like zero-tillage and bed planting, because they are profitable and add value to the system as a whole.

Advances in this context will depend on the investment in public research which is currently much less than what existed between 1966 and 1985. Work on resource conservation technologies like zero tillage in Uttar Pradesh under NATP project has been found to increase productivity in crops like wheat. Retaining and management of adequate amount of crop residues (at least 30%) under conservation agriculture is the key to realize long-term benefits and also to reverse the process of soil degradation. In a soil that is not tilled for many years, the crop residues remain on the soil surface and produce a layer of mulch.

Retention of crop residues improves organic carbon content, water stable aggregates, bulk density, and hydraulic conductivity and reduces run-off. But most of the farmers in Haryana and Punjab burn the crop residues to get their fields well cleaned before sowing of rabi wheat. Therefore, to replace residue burning, and to realize benefits of residue cover under conservation agriculture, its efficient management through machinery modification is the need of time.

5.4.2. Crop residue management

The importance of maintaining trash cover has long been recognized. However, this often interferes with the placement of seed in firm and moist soil; therefore, farmers frequently burn the fields which is not an eco-friendly practice. Seed could be placed in the soil in anchored stubble condition after partial burning for removal of loose straw. Even such partial burning is neither safe nor eco-friendly. Uniform spreading of straw during harvesting itself by mounting a device at the rear of combine and then using drills under loose straw condition or chopping loose as well as anchored stubbles with a rotary shredder followed by residue drills are some of the viable options. The rice straw can be collected and used as mulch, for some crops. Mulching with straw has favourable effect on the yield of maize, soybean and sugarcane crops. It also results in substantial saving in irrigation water. Rice straw mulching in the no-till sown wheat with a newly developed Happy seeder machine is being tried. Happy seeder does cutting, lifting and spreading the standing rice stubbles and loose straw along with sowing in one operation. Rice residue collection and mulch application result in additional cost of Rs.2000 per hectare. The incorporation of the residues has favourable effect on soil physical, chemical and biological properties such as pH, organic carbon, and water holding capacity and bulk density of the soil **(**Singh *et al*., 2005**).**

Field experiments on the rice-wheat cropping system show that incorporation of crop residues can increase soil organic C and total N contents. Incorporation of crop residues increased organic C by 14-29 per cent over residue removal treatments in 3-10 years of experiments. In an 11 years field experiment on a loamy sand soil in Punjab, the incorporation of residues of both crops in the rice-wheat cropping system increased the total P, available P, and K contents in the soil over the removal of residues. The total P, and available S were in the order of residue incorporation > residue removal > residue burning. In another study over a 5-year period on a silt loam soil at Palampur in Himachal Pradesh having a relatively cooler climate than Punjab, the incorporation of rice straw in wheat caused a slight increase in a availability of P, Mn and Zn and a marked increase in the availability of K. The incorporation of crop residues on a long-term basis increased the DTPA-extractable Zn, Cu, and Fe.

5.4.3. Furrrow-irrigated raised bed system (FIRBS)

It is a very useful technique for introducing inter-cropping and crop diversification. However, yield penalties at some locations and overall economics under FIRBS pose a question mark on the success of this technique. Similar results have been realized in direct seeded and transplanted rice under FIRBS in rice-wheat growing areas of Haryana. Other techniques including zero-tillage in transplanted rice and zero-tillage direct-seeded rice call for efforts to be shifted from wheat to rice for measures to conserve resources. Based on multi-locational farmers' field trials in Haryana during 2001 and 2002, it was realized that puddling, the most common practice followed by the growers in rice, is not necessary to achieve higher grain yields. Successful crop growth and comparable grain yields of rice crop under zero till-transplant and unpuddled-transplant (dry field preparation fb irrigation prior to transplanting) were attained during both the years. Direct seeded rice under zero-tillage, and puddled and unpuddled situations could be other options for raising this crop and avoiding tedious practice of transplanting.

5.4.4. Permanent bed

In the context of conservation agriculture, where soil is essentially biologically tilled, bed planting has significant role in enhancing the eco-friendly cultivation with higher productivity and profitability of various cropping systems. The important crop rotations, which virtually can directly go for permanent bed planting, are soybean-wheat, maize-wheat, pigeonpea - wheat; maize – vegetable - wheat; maize – toria / mustard-wheat; pigeon pea + mungbean / urdbean wheat etc. Even direct seeding of rice in some cases produces similar grain yield with earlier maturity. This provides a chance to grow short duration vegetable pea/potato followed by wheat to enhance the crop and soil productivity as well as cropping intensity. The inter-cropping of sugarcane and wheat in autumn would enhance the wheat area and production and simultaneously sugarcane productivity. Three (3) years study of eight (8) crop sequences showed that diversification/interruption of rice-wheat system, once in three years, always enhanced the net return, when all crops (except rice) were grown on raised bed in a system approach. Inclusion of oilseed or pulses once in three years or intensification by growing vegetable pea in between rice and wheat or green gram after wheat showed higher return as compared to conventional rice-wheat system. Among the various agricultural commodities, the vegetable oils and pulses contributed about Rs 87,448 and Rs 25,626 million, which worked out to 51.1 and 14.9 per cent of total agricultural imports (2002-03), respectively. Enhancing the productivity of oilseeds and pulses and simultaneously backing it by marketing and processing structure could minimize this to a great extent. By 2016-17, India has however achieved near self-sufficiency in case of pulses, but continues to spend about Rs. 700,000 million on vegetable oil imports.

5.4.5. Integrated watershed management

Watershed management is an approach of area planning of natural resources especially land, water and plants to sub-serve the socio-economic needs of human society or community based on sustainable eco-system principles. It is divided into two parts i.e. (i) catchment area: land area contributing water to a given point from where it can be recycled in addition to recharging the profile; and (ii) command area - where water is utilized in an effective manner depending upon the catchment area/capacity of reservoir. This is the only approach which can sustain the productivity of different cropping systems under rainfed or under limited irrigation conditions. Upper catchment and foothill regions of several states provide the greatest scope for rain water harvesting and ground water recharge because of favourable hydrological formations and heavy rainfall.

5.4.6. Precision agriculture

Precision or site-specific crop management refers to a management system of production agriculture, using diverse technologies to increase field productivity and protect the environment. Under precision agriculture, however, inputs are applied in each part of the field according to its unique set of conditions. Moreover, when to apply, how to apply, how much to apply, kind of inputs in relation to water, nutrient, pesticides etc., the residual effect nutrient and crop residue and left over water on the succeeding crop and their behavior with the environment in time and space are studied from a very close angle, so that resource wastages may be reduced to minimum possible.

Normally, farmers follow one uniform practice of application of water, nutrient and pesticides at their farm. However, in this concept the variation observed within each field is to be taken care of. Each field is to be visualized critically and assured of balanced supply of nutrients in desired amount in every nook and corner to achieve sustainable yield levels of different cropping systems.

5.4.7. Integrated nutrient and pest management

To ensure adequate and balanced nutrient supply, integrated approach is an important option and involves more efficient use of chemical fertilizers in conjunction with judicious combination of organic manures without detriment to soil fertility and improving crop productivity. The high cost of fertilizers coupled with relatively greater losses of fertilizer N leading to environmental pollution and yield decline over the years, calls for cost effective and sustainable measures to improve productivity & profits. Integrated nutrient supply helps to improve the physical, chemical and biological health of soil and avoids soil degradation and deterioration of water and environmental quality by promoting carbon sequestration and checking the losses of nutrients to water bodies and atmosphere.

Besides, organic source of nutrient serves as slow release fertilizer as it synchronizes the nutrient demand set by plants, both in time and space, with supply of the nutrients from the labile soil and applied nutrient pools. Research investigations have further reported that use of green manure before paddy transplanting not only help to save 50 per cent of recommended NPK, but also improve the soil fertility. Likewise, 50 per cent substitution of NPK through farm yard manure also help both the crops in rice-wheat system along with fertility improvement. Another significant investigation for realizing the high yield of paddy, the recommended chemical fertilizers should be supplemented with crop residues and green manuring (Bhandari and Walia, 2000).

5.4.8. Crop diversification

Many scientists conclude that diversification of RWCS (rice – wheat cropping system) is the only answer to sustain the productivity of the cropping system. Based on such recommendations, policy makers planned replacement of part of rice-wheat cropping system through diversification. However, the average profitability of RWCS was found to be higher than alternate cropping system. Results of diversification so far have been unimpressive. Alternate cropping system can prove beneficial, if inter-crop yields and prices can result in comparable profit.

The RWCS does seem to need diversification. However, farmers are not happy with the relative profit offered by diversification. Any research output is good if it attracts farmers and is bad if it repels them. There may be an opportunity for large scale introduction of resource conservation technologies (RCTs). The balancing effect of RCTs will allow RWCS to maintain the ecosystem without having to diversify on a large scale. There is need for research to develop appropriate models for sustainability based diversification. More importantly, the farmers need to be educated and convinced about alternate cropping systems.

5.4.9. Role of legumes in systems

Legumes are known to increase soil fertility through their capacity to fix atmospheric-N and hence the soil fertility can be improved by inclusion of a legume in the cropping system. Yield of cereals following legumes are reported to be 30 to 35 percent higher than those following a cereal in cropping sequence. Beside N-fixation, legumes also help in solubilization of P, increase in soil microbial activity, organic matter restoration and improvement of physical health of soil. Results from the All India Coordinated Research Project on Cropping Systems showed consistent better productivity from rice-pulse than rice-wheat systems. The benefits of legumes in rotation are not solely due to biological nitrogen fixation, but result from improved soil structure, reduced disease incidence and increased mycorrhizal colonization. Growing of legume as green manure (*Sesbania aculeate* L.) helped to save 60 kg nitrogen for the succeeding paddy crop.

5.4.10. Laser land levelling

Land levelling is a precursor to good agronomic, soil and crop management practices and the levelness of the land surface has significant influence on all the farming operations. The soil moisture status throughout the field governed by its levelness has great influence not only on farming operations but also the yield and input use efficiency.

The levelling of land for achieving higher resource use efficiency is not a new technique, but many a time it is not achieved to a satisfactory level. Undulated land hampers seedbed preparation, seed placement and germination.

The general practice of N application in India is through broadcasting of urea. Under uneven soil surface, the applied N is either washed away from higher elevating points to lower elevating points or leached down in low lying points which results in low use efficiency. If field is perfectly levelled, the uniform distribution of N will leads to better use efficiency and higher yield levels.

5.4.11. Contract farming

Contract farming involves agricultural production being carried out on the basis of an agreement between the buyer and farm producers. Sometimes it involves the buyer specifying the quality required and the price, with the farmer agreeing to deliver at a future date. More commonly, however, contracts outline conditions for the production of farm products and for their delivery to the buyer's premises. The farmer undertakes to supply agreed quantities of a crop or livestock product, based on the quality standards and delivery requirements of the purchaser. In return, the buyer, usually a company, agrees to buy the product, often at a price that is established in advance. The company often also agrees to support the farmer by way of supplying inputs, assisting with land preparation, providing production advice and transporting produce to its premises. The term "outgrower scheme" is sometimes used synonymously with contract farming, most commonly in Eastern and Southern Africa. Contract farming can be used for many agricultural products, although in developing countries it is less common for staple crops such as rice and maize.

Contract farming has been used for agricultural production for decades but its popularity appears to have been increasing in recent years. The use of contracts has become attractive to many farmers because the arrangement can offer both an assured market and access to production support. Contract farming is also of interest to buyers, who seek supplies of products for sale further along the value chain or for processing. Processors constitute the main users of contracts, as the guaranteed supply enables them to maximise utilization of their processing capacity. Contracts with farmers can also reduce risk from disease or weather and facilitate certification, which is being increasingly demanded by advanced markets. Although contract farming must first and foremost be considered as a commercial proposition, it has also come to be viewed as an effective approach to help solve many of the market access and input supply problems faced by small farmers. Effective linkages between companies and thousands of farmers often require the involvement of formal farmer associations or cooperatives or, at least, informal farmer groups.

5.4.12. Organic farming

Organic agriculture is recognized as an innovative farming system that balances multiple sustainability goals and will be of increasing importance in global food and ecosystem security (Reganold and Wachter, 2015). High demand for organic foods in Europe and North America has resulted in the import of organic foods from large farms in less-developed countries (Willer, H. and Lernoud, 2015).Organic agriculture relies on location specific varieties (resistant/tolerant to pest and diseases), crop rotation, organic composts, green manure, biological pest management and prohibits the use of synthetic fertilizers and pesticides, antibiotics, genetically modified organisms, and growth hormones. Concerns about the un-sustainability of conventional agriculture have promoted interest in other farming systems, such as organic, integrated and conservation agriculture (CA). Organic farming has the potential to produce high quality food, enhance natural resource base and environment, increase income and contribute to the wellbeing of the farmers (Reaganold and Wachter, 2016).

5.4.13. Integrated farming systems

Integrated farming system (IFS) is an entire complex of development, management and allocation of resources as well as decisions and activities, within an operational farm unit, or combinations of units, that result in agricultural production, processing and marketing of the products. IFS is a whole farm management approach that combines the ecological care of a diverse and healthy environment with the economic demands of agriculture to ensure a continuing supply of wholesome, affordable food. It is a dynamic concept which must have the flexibility to be relevant on any farm, in any country, and it must always be receptive to change and technological advances. Above all, IFS is a practical way forward for agriculture that will benefit the society, not just those who practice it.IFS can be defined as a positive interaction of two or more components of different nature like crops, live stocks, fishery, trees etc. within the farm to enhance productivity and profitability in a sustainable and environmental friendly way. A judicious mix of two or more of these farm enterprises with advanced agronomic management tools may compliment the farm income together with help in recycling the farm residues. The selection of enterprises must be based on the cardinal principles of minimizing the competition and maximizing the complementarity between the enterprises.

5.5. Annotation

Good Agricultural Practices (GAPs) are production standards that were developed to reduce the risk of contaminating agricultural products with disease-causing microbes or other harmful materials. The standards target potential sources of contamination in the production chain, including water, soil, animals, people, and equipment. GAPs cover the farm operation and production activities up through field packing. An additional, related set of standards (sometimes referred to as GHPs, or Good Handling Practices) come into play for farms that have on-site packing and storage facilities.

The produce industry, motivated by concerns about food safety, has been the driving force behind GAPs. Growers who adopt good agricultural practices can go through a voluntary auditing process to verify that they follow the standards. Successful completion of an audit results in GAP-certification for the grower.

The United States Department of Agriculture (USDA) and a number of private companies in US offer auditing services, for a fee. However, audits differ depending on the commodity and the organization conducting the audit. For example, as a vegetable that can be eaten raw, broccoli is considered a "leafy green" for food safety purposes, thus higher standards (and a stricter audit) are necessary.

The approach of FAO to GAP is non prescriptive, and in line with guidance received from COAG. FAO does not define a rigid set of principles but provides a technical reference for concerned stakeholders to assess existing GAP schemes and, using best expertise available, develop locally-appropriate good agricultural practice programmes.

In India, there is need to develop a system of auditing & certification of GAP.

Key Extracts

- Good agricultural practice is a collection of principles to apply for on-farm production and post-production processes, resulting in safe and healthy food and non-food agricultural products, while taking into account economical, social and environmental sustainability.
- The main objectives of GAP are to ensure safety and quality of produce in the food chain and to capturing new market advantages by modifying supply chain governance.
- Adoption of GAP helps promote sustainable agriculture and contributes to meeting national and international environment and social development objectives.
- The GAP applies recommendations and available knowledge to addressing environmental, economic and social sustainability for on-farm production and post-production processes resulting in safe and healthy food and non-food agricultural products.
- Demand for agricultural crops is expected to double as the world's population reaches 9.1 billion by 2050. Increasing the quantity and quality of food in response to growing demand will require increased agricultural productivity. Good agricultural practices, often in combination with effective input use, are one of the best ways to increase smallholder productivity. Many agri-businesses are building sustainable supply chains to increase production and improve quality.

Chapter 6
Recommendations and Policy Framework

6.1. Watershed Development

- Promote transparency, accountability, and stakeholder involvement and collaboration through governance and coordination mechanisms particularly at the micro-watershed level
- Understand the principles of Integrated Watershed Management (IWM) and adopt at the local village level and establish a new standard for governance. As trends in watershed management continue, develop an effective delivery mechanism that will energize stakeholders, recognize contributions made, and celebrate community successes.
- A wide spectrum of tools needs to be applied -- a "one size fits all" approach is not effective to deal with the increasing complexity of watershed management issues. Apply customized approach to suit various situations and challenges. Application of voluntary guidelines, promotion of targeted watershed policies, and consensus-based tools are the need of the hour.
- Institutionalise the program as per the need of people, making it a demand-based and participatory initiatives. Optimise use of the local resources and make best use of these for conservation & sustenance of land & water and in the process ensure livelihood generation for the people of the area; and strengthen linkages between researchers and decision-makers across governments and other stakeholder.
- Develop guidelines for monitoring of watershed projects; build data collection networks, modelling, and develop indicators to report on soil health and water quality.
- Develop and improve decision making through use of geo-spatial technology tools to analyse and guide watershed management decisions, particularly at the micro-watershed scale, through research and development of integrated models.
- Undertake and further evaluate various mechanism and approaches to better understand what works, where, and under what circumstances, with a view to sharing information on best practices.
- Enhance the availability of real time precise scale data and information on factors important to IWM -- such as land use and cover, slope, erosion soils depth and water quality, use, and availability -- through surveys, monitoring, and enhancement of databases at an appropriate scale.
- Strengthen and improve socio-economic and physical science for water management, as a key strategy for helping address the challenges
- Promote tank-based watershed development by including tank rehabilitation as a component of local watershed development activity

- Advocate supportive policies to aid community action in conservation and development by interacting with the local, state and central governments.

6.2. Water in Rainfed Areas

- Optimize the balance between centralized water management and services with community water ownership and management. For example, the Hiware Bazar project to revitalize groundwater, community operated water supply systems in Punjab, farmer management groundwater systems in Andhra Pradesh and by the DHAN Foundation, have lot of learnings that can be replicated.
- Invest in creating effective grassroot level water groups through which change can be driven and availability, quality, and efficiency of water use can be improved.
- Impart specialized training on participatory irrigation management (PIM) programs and knowledge for effective implementation. The water users in the command area need to be mobilised around a common purpose of water use efficiency.
- Emphasise business cases and not just water conservation. There are examples demonstrating that farmers are more likely to adopt micro-irrigation when they see yield benefits and reduced yield risks than simple water conservation.
- Adopt a comprehensive - full-system view of the problem and design and implement integrated programs that bring together different elements. A good example is Integrated Drought Adaptation initiative in Andhra Pradesh state that brought together 19 initiatives as diverse as village seed banks, crop diversification, groundwater management initiatives, in order to make farming in the state resilient and adaptive to droughts.
- Create a multi-tier institutional structure comprising village associations, cascade associates, and block-level tank user associations all supported by competent village level water managers for sustainability of such a program.
- Identify effective and inspirational role model farmers who can galvanize large communities and accelerate adoption and buy-in.
- Promote micro-irrigation (MI) systems as production enhancement and income enhancement proposition rather than as a technology that merely saves water for farmers. Of course, the key is the integrated perspective where the MI systems are coupled with improved agronomic practices like, low water duty crops, fertigation and use of solar pumps.
- Demonstrate the science of geo-hydrology and empower farmers with the knowledge, skills and equipment to measure and monitor available water resource and plan sustainable water use.
- Keep community organizations vibrant even after formal closure of the project to ensure a continuous dialogue for overall sustainability.

- Design a comprehensive ICT program that includes mass media, school and community level activities, as well as door-to-door engagement all blended with information technology (IT).
- Establish the association between various land use practices and their adverse impact on the storage capacity of the reservoir to demonstrate to the farmers that they need to adopt right and sustainable land use practices.
- Form Village Water Supply Committees for self-management of rainwater harvesting, equitable and regular water supply and revival of traditional water bodies.
- Delineate Rainfed Agro-Economic Zones (RAEZ) with participatory watershed development and integrated farming systems approach.
- Develop agro-ecology specific Potential Rainfed Crop Zoning for bridging yield gaps by developing commodity crop-centric value chains, providing safety nets (weather based crop insurance), crop intensification/diversification/substitution, contingency plan implementation on real-time basis, crop planning based on market intelligence/ crop zoning/alignment to regulate cropped area and production to realize higher commodity prices.
- Harvest groundwater potential judiciously and adopt efficient water management in *daira* lands in eastern region of the country.
- Implement and popularize agro-ecology specific in situ rainwater management practices on individual/community basis as mandatory activity of state line departments for higher moisture and nutrient use efficiency.
- Map potential sites for rainwater harvesting in farm ponds with catchment-storage-command area relationship approach.
- Desilt village tanks to increase volume of water for irrigation of crops and groundwater recharge/stabilization.
- Promote construction of household soak pits and tree planting in schools, backyards and along streets by the community (especially children) in villages.
- Develop Land Resource Inventory (LRI) at cadastral level (1:10000 scale) for site-specific nutrient management/integrated nutrient management, balanced nutrition and reducing input costs.
- Establish processing and value addition units at strategic places in the rural areas/production areas for pulses, millets, fruits, vegetables, dairy, fisheries and poultry in public private-partnership (PPP) mode.
- Increase the reach of farm mechanization to small and marginal rainfed farmers with cost effective, energy efficient and crop-specific farm equipment. Promote custom hiring centres to provide the farmers easy access to farm machinery, like combine harvester, laser guided land levellers, rotavator etc., for small and marginal farmers.

Create hubs for hi-tech & high value farm equipment relating to vegetables and fruit crops.

- Establish, monitor and forecast climatic extremes by creating virtual weather stations at microlevel; weather index based crop insurance; value-added weather management services (include delineation of climate vulnerable zones at micro-level, real time agromet-advisories, climate predictions and pest & disease forewarning systems).
- Ensure capacity building for at the local level for drought preparedness planning; vulnerability mapping in preparing the community level drought management plans, in livestock and dairy sectors; agromet-advisory services etc.
- Ensure economic incentives for rainwater/crop residue management practices, biomass production, carbon sequestration.
- Develop convergence of national/state programmes/schemes for drought proofing at micro-level.

6.3. Integrated Farming System

- Harness supplementary and complementary relationships of crop, animal husbandry, poultry, fisheries, multipurpose trees systems through integrated farming system (IFS), particularly in case of small & marginal farmers.
- Promote IFS as a means for doubling farmers' income, improving food, nutrition, employment and income of the small and marginal farmers and as a coping mechanism to climate change.
- Promote non-renewable resources and their efficient use in farming system.
- Promote kitchen gardening for both rural and urban households for improving nutrition; and focus on improving the extension services for this purpose.
- Prioritize location specific regionally differentiated interventions along with integrated farming focussing on water and nutrient management.
- Develop contingency crop planning, keeping in view the extreme weathers and water availability in a region for various crops/ livestock.
- Adopt promotional policy for crop/plant residue recycling through composting and vermicomposting; and laws against residue burning.
- Renovate and maintain farm ponds especially community ponds for promoting fish based farming systems and lifesaving irrigation at village level through integration of various government schemes meant for creating community assets and job for rural poor. These schemes include MNREGA, Tribal Sub Plan (TSP), RKVY - RAFTAR etc.
- Promote orchard based farming system for additional income and assurance against climate anomalies.

- Promote farm resource linked activities at both farm and village levels. The resources include crop by-products like paddy straw, cotton stalk etc. Activities like mushroom cultivation, beekeeping etc. will generate much needed additional incomes. Also promote secondary activities such as tailoring, weaving, food processing, etc. as components of IFS for additional income and employment.
- Encourage farmers to use warehouses and avoid distress sales and prevent post- harvest losses by focussing on setting up storage facilities and integrated cold chains in rural areas.
- Evolve agro-ecology specific rainfed IFS models by identifying and modernising traditional farming systems.
- Promote agro-ecology-specific alternate land use systems/ agro-forestry systems based on land capability in private and public lands.
- Promote pasture, silvi-pasture systems, fodder trees, multiple tree based systems in non-arable lands, particularly in village common lands.
- Go for boundary plantation with perennial tree species for forage, green leaf manure, mulching and ecosystem services for moderating microclimate at individual farm level

6.4. Organic farming

- Promote organic farming in regions with poor endowments like rainfed & hilly tracts, where consumption of external inputs is low and per hectare yields are also low.
- Promote niche-based organic farming in crops, commodities and regions where the country has comparative advantage. To begin with, advocate organic farming for low volume high-value crops, like spices, medicinal plants *etc.*, besides, fruits and vegetables along with R&D support.
- Organic farming has high potential in NE region, hill states and other rainfed areas and this may be strengthened with adequate technological backstopping along with need based input support system, marketing and value addition. About 1 million hectare area now under forest (shifting cultivation) can be brought under organic certification easily with suitable interventions and needed support.
- There is scope to bring about 14 million ha (10 per cent of net cultivated area) under organic farming. Promote cluster based organic farming so that efficiency of scale can be brought to bear upon the practice at both pre-production an production stages.
- Facilitate region-specific resource inventory, including animal wealth, farm residues/by products and their competitive uses, non-conventional nutrient sources of organic/biological origin *etc.* for development of rational research-based technology packages of organic farming. The availability of organic manures in adequate amounts and at affordable costs to the farmers is essential.

- Standardize technologies for on-farm recycling/rapid composting of on-farm res*idue*s and wastes to meet at least 80 per cent N, P and K requirements and strengthen extension efforts to change the mind-set of the farmers.
- Leverage entrepreneurial potential with respect to production of organic inputs, processing and marketing of organic food to enable start-ups to address all critical steps *viz*., organic inputs (bio-fertilizers/bio-inoculants, bio-pesticides), processing, packaging materials, marketing *etc.*
- Organic standards in practice in the country are derived from US and European standards. Develop national certification protocol and regulatory legal framework for organic certification standards coherent with Codex Alimentarius.
- Educate farmers about the importance of adopting certification standard – PGS (Participatory Guarantee System), NPOP etc. Certification Agencies also need to be promoted in adequate number.
- Promote a strong research back up to develop and improve national standards for organic farming. Set up robust research laboratories to monitor the quality of organic produce so as to prevent the sale of substandard material. Develop food quality parameters of organically produced food comparable with conventionally produced food and display on organic products to gain consumer confidence.
- Whereas organic systems yield less food, organic foods have significantly less to no synthetic pesticide residues compared with conventionally produced foods. It has been proved through a network of research system "Network Project on Organic Farming (NPOF)" in India, that when practised prudently and in the context of agro-climatic conditions, crop and soil type, organic farming can give as good a yield as conventional farming.

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Abbreviations

A4NH	Agriculture for Nutrition and Health
AADs	Agricultural Associated Diseases
AARDO	African-Asian Rural Development Organization
AAU	Anand Agricultural University
AC&ABC	Agri-Clinic and Agri-Business Centre
ACCNet	Agricultural Credit and Cooperation Network
ADB	Asian Development Bank
AE&AS	Agricultural Extension and Advisory Services
IGP	Indo Gangetic Plains

Annexures

Annexure-I

Time of application of Panchagavya for different crops is given as follows.

Crops	Time schedule
Rice	10, 15, 30 and 50th DAT
Sunflower	30, 45 and 60 DAS
Black gram	Rainfed: 1st flowering and 15 DAF Irrigated: 15, 25 and 40 DAS
Green gram	15, 25, 30, 40 and 50 DDAS
Castor	30 and 45 DAS
Groundnut	25 and 30th DAS
Bhendi	30, 45, 60 and 75 DAS
Moringa	Before flowering and during pod formation
Tomato	Nursery and 40 DAT: seed treatment with 1 per cent for 12 hrs
Onion	0, 45 and 60 DAT
Rose	At the time of pruning and budding
Jasmine	Bud initiation and setting

Annexure II

Location Specific nutrient management packages.

Location (State)	Cropping System (s)	Sources to meet nutrients
Coimbatore (Tamil Nadu)	Cotton-maize-green manure (GM) Chillies-sunflower-green manure	Farm Yard Manure (FYM) + Non Edible Oil Cakes (NEOC) + Panchagavya (PG)
Raipur (Chhatisgarh)	Rice-chickpea	Enriched compost (EC) + FYM + NEOC + Bio dynamic (BD)+PG
Dharwad (Karnataka)	Groundnut-sorghum Maize-chickpea	EC + VC + Green leaf manure (GLM) + biodynamic and PG spray
Ludhiana (Punjab)	Maize-wheat-summer green gram	FYM + PG + BD in maize, FYM +PG in wheat and FYM alone in moong
Bhopal (Madhya Pradesh)	Soybean-wheat Soybean-chickpea Soybean-maize	FYM+PG + BD
Pantnagar (Uttarakhand)	Basmati rice-wheat-green manure / Basmati rice-chickpea / Basmati rice-vegetable pea	FYM + VC + NC + EC + BD + PG
Ranchi (Jharkhand)	Rice-wheat-green manure	VC+ Karanj cake + BD+ PG
Umiam (Meghalaya)	Maize+soybean-Frenchbean/Carrot	FYM + VC + NC + RP

(Source: NPOF)

Annexure III

Identified pest and disease management packages at various locations for different cropping systems (*Source*: NPOF).

Location (State)	Cropping System	Pest/disease	Recommended practice
Modipuram (Uttar Pradesh)	Basmati rice-chickpea	Soil borne pests and diseases	Summer ploughing + green manure incorporation
Calicut (Kerala)	Ginger	Shoot borer	Seed treatment with Ginger Endophytic Bacteria 17 & 18, Ginger Rhizobacteria 57
Bajaura (Himachal Pradesh)	Cauliflower-peas-tomato	Fruit borer and fruit rot	Karvi (*Royleacinerea*) @ 10 per cent aqueous leaf extract + cow urine (3 per cent) + tween-80 (0.05 per cent) as emulsifier
Umiam (Meghalaya)	Maize + Soybean	Monolapta Mylloceros Ephilechna Leaf folder	Derisom (3 ml/l) + Panchagavyya @ 10 per cent and cow urine 3 per cent - Anomin 3 ml/litre or Panchagavyya @ 3 per cent.
		Rust	Panchagavyya @ 3 per cent + Lantana @ 10 per cent + Vermiwash @ 10 per cent

Annexure IV

Identified weed management packages for various locations and cropping systems.

Location (State)	Cropping System	Recommended practice
Raipur (Chhatisgarh)	Rice-mustard	Conoweeder with square planting for rice Stale seed bed for mustard
Coimbatore (Tamil Nadu)	Rice-black gram-green manure	2 hand weeding + spray of aqueous leaf extract at 3-4 leaf stage of weeds
Dharwad (Karnataka)	Groundnut	Spray of *cassia* and *Prosopisjuliflora*as post emergent
Ludhiana (Punjab)	Basmati rice-wheat-green manure	High density planting + hand weeding at 25-30 DAT
Pantnagar (Uttarakhand)	Basmati rice-wheat-green manure	One hand weeding at 25-30 DAT during *kharif* and 2 hand weeding at 25-30 and 45-50 DAS during *rabi*
Umiam (Meghalaya)	Maize (green cob)-mustard	Mulching with fresh Eupatorium / Ambrosia @ 10 t/ha (after earthing up)

Annexure V

Recommended farming Systems and interventions based on farmer participatory research.

State	District	Recommended farming systems	Area (ha)	Suggested interventions	Improvement in production on equivalent basis over bench mark (%)
Andhra Pradesh	Srikakulam	Field crop + dairy (1 cow)	0.80	Rice-green gram-Sesame, fruit orchard (0.2 ha), Cow, BYP (25 no's), nutritional kitchen garden, Vermi composting	312
Assam	Kamrup	Field crops + Cow(2)+ Poultry(10) + Pig(2)	0.77	1. Replacement of local Poultry with improved Breeds (Bonraja -10 nos) 2. Replacement of local breeds of pigs with improved ones (Hampshire) 3. Mineral mixture to cows 4. Deworming in Cow and Pig	65
Chhattisgarh	Kawardha	Field crops (0.80 ha) + Dairy (cow 1-2)	0.80	Pigeonpea in bunds, vegetable (tomato chilli, beans) in bunds + Goat + poultry(30) + vermicomposting + Kitchen garden + mushroom + fruit tree in boundary	61
Gujarat	Mehsana	Field crops (0.65 to 0.70 ha) & for Dairy 0.25-0.30 ha land 2-3 Buffalo/cow & Buffalo or cow	0.98	**Crops Intensification** -Hy. Castor + Lucern (F+S) Broadcasting -Hy. Castor+Chicory (f) Broadcasting - Hy. Cotton + Hy. Castor -Mustard + Luceern (S) **Diversification** -Hy. Castor-Fennel/chilly Wheat –Rabi fennel F jowar-F bajara Animals: Supply of Green fodder Mineral mixture dewarming **Product diversification** Vermicompost, enrichment of wheat straw, Kitchen gardening, chilly powder.	14
Gujarat	Panch	Field crops	0.98	**Crops Intensification**	21

State	District	Recommended farming systems	Area (ha)	Suggested interventions	Improvement in production on equivalent basis over bench mark (%)
	mahal	(0.65 to 0.70 ha) & for Dairy 0.25-0.30 ha land 2-3 Buffalo/cow & Buffalo or cow		Miaze—Maize Paddy (UL)—Maize **Diversification** Guar/Bt cotton Mineral mixture dewarming **Product diversification** Vermicompost, enrichment of wheat straw, Kitchen gardening, chilly powder.	
J&K	Samba	Field crop(0.59) + dairy (cow/Buffalo 1)	0.59	High yielding variety of maize (kanchan) + Blackgram (1:1)-Wheat, Rice-wheat, Balance nutrition (NPK& Znso4), Feed supplement through mineral mixture to animal, Back yard Poultry (Vanraja), Button & oysters Mushroom, NKG (Broccoli, palak, garlic, onion etc.)	78
Jharkhand	Pakur	Crop+Pig	0.83	Rice-Wheat+ Mustard (8:2), Pig	37
Karnataka	Kolar	Field crops (0.96 ha) + Buffalo/cow (2-3)	0.96	Improved varieties in Finger millet, Redgram and Maize + Use of micronutrients and Biofungicides+ enrichment of FYM before application+ improved breed of Backyard poultry birds Swarnadara+ Sheep (Bannur)+ Azolla+ Vermicomposting unit + Multipurpose tress+ Improved varieties of fodder+ Cowmat+ chuff cutter+ Kitchen garden kit+ Sericulture kit+ Trainings	33
Karnataka	Gadag	Field crop(0.84)+ Buffalo/cow (1-2)	0.80	Green gram+ Cotton (2:1) Groundnut +Cotton(2:1) + poultry(10 birds)+ Hybrid Napier on bunds + mineral mixture+ bio composting +value addition to milk	30
Kerala	Pathanamthitt	Crop (0.2 ha)	0.47	Rice (var.Uma) + Coconut (Mineral nutrition	54

State	District	Recommended farming systems	Area (ha)	Suggested interventions	Improvement in production on equivalent basis over bench mark (%)
	a	+ Horticulture (0.27 ha) + Dairy (1 no.)		with Mg &K at 1 & 2 kg respectively) + Banana (intercrop)+ Dairy (mineral mixture) + Nutritional Kitchen garden	
Madhya Pradesh	Dindori	Field crops (0.76 ha) + Dairy (cow/Bufalo 1-2)	0.76	Soybean-lentil, Green fodder (MP Chari and Berseem), Mineral Mixture and De – Worming , AI	59
Madhya Pradesh	Katni	Field crops (0.73 ha) + Dairy (cow/Bufalo 1-2)	0.73	Paddy-Wheat/Gram, Green fodder (MP Chari and Berseem), Mineral Mixture and De –Worming, A.I	43
Maharashtra	Pune	Field crops (0.53 ha) + Buffalo/cow (1-2)	0.53	Soybean-onion, Paddy - Wheat, Pearl millet-Chickpea/ Hybrid Napier in bunds, Goat (1)/Poultry(10)	16
Maharashtra	Amravati	Field crops (0.76 ha) + Buffalo/cow (1-2)	0.76	Soybean + Pigeonpea (4:2) Chickpea + linseed (5:1) – Summer sesamum + Goat (1) +Hybrid Napier in bunds + Ber Budding + compost with bio decomposers + Kitchen garden	27
Maharashtra	Palghar	Crop + Dairy	0.40	Rice – cluster bean, buffalo(1)/cow(2),goat (1), poultry bird(2), forage grass/crop, mineral mixture, vermicompost, value addition of food grain and milk, trainings on crop and livestock management	52
Odisha	Angul	Crop + Dairy	0.80	Hybrid maize for green cobs & green fodder + off-season cauliflower and tomato +pruning of fruit trees + dual purpose poultry bird breed *Chhabro*+ Azolla cultivation +Mineral mixture, deworming, preventive vaccination to cows	48

State	District	Recommended farming systems	Area (ha)	Suggested interventions	Improvement in production on equivalent basis over bench mark (%)
Rajasthan	Udaipur	Field crop (0.57 ha) + Buffalo/Cow (2 no.)	0.57	Maize- wheat crop sequence, growing of vegetables namely tomato, brinjal, chilli , okra, onion, bottle gourd, ridge gourd etc. cultivation (in 0.2 ha area) + mineral mixture, deworming and cut fodder (dry and green) to cattles + 20 no. of Pratapdhan poultry + vermicompost preparation	101
Tamil Nadu	Sivagangai and Pudukkottai	Field crops (0.8 ha) + Cow (2-3)+ poultry (4-5)	0.80	Rice (SRI) – Groundnut (VRI 7)+ Blackgram (VBN 5) + Cumbu Napier hybrid (0.02 ha) + Mineral mixture (40 gm/animal/day) + Giriraja poultry (8 +2) +Cleaning and grading of grains + vermicomposting + Kitchen garden + training	41
Telangana	Warangal	Crop+ Diary (Field crop + Buffalo (2-3))	0.90	Green gram-Rice-zero tillage maize Cotton + red gram (4:1/6:1) Improved desi birds, APBN-1 perennial fodder and Lucerne, Nutritional kitchen gardening, vermi composting, selling of milled fine rice and Azolla production	65
Uttarakhand	Nainital	crops (0.2 ha) + Local cow (1-2) +Goatry(2)+ Poultry(20)	0.20	High value vegetables like coriander, chilli, pea, onion, cucurbits & papaya +Hybrid Napier on bunds, maize+cowpea-egyptianclover-maize+cowpea + vermin-compsting, organic Kitchen garden & grading & packing of vegetables before marketing	108
West	South	Field crops (	0.34	Onion /Okra	55

State	District	Recommended farming systems	Area (ha)	Suggested interventions	Improvement in production on equivalent basis over bench mark (%)
Bengal	24 Parganas	0.34 ha) + dairy (1-2) + fishery		+ poultry with vaccination and Azolla feeding + mineral mixture feeding and vaccination with deworming of cow + cultivation of mixed carp with proper ratio and fertilization	
Meghalaya	Ri-Bhoi	Fish (farm pond) + vegetables+ field crops + dairy (1 cow + calf) + fodder + fruits + vermicompost + hedgerow species	0.43	Year round vegetables in Ktichen garden in alternate beds as per the season. Diversion of cattle shed washings to farm pond. Leguminous hedge row species on boundaries and fences. Raised and sunken beds on lowlands for vegetables. Pond dyke intensification for cultivation of cucurbits and fruits.	166

Annexure VI

Identified high productive systems for selected locations

Locations	Prevailing system			High Productive system		
	System	**System Yield (REY) (t/ha)**	**Net returns (x10^3 Rs/ha)**	**System**	**System Yield (REY) (t/ha)**	**Net returns (x10^3 Rs/ha)**
Jammu, J&K	Rice-wheat	11.3	68.6	Rice-marigold-french bean	30.1	168.0
				Rice-potato-onion	29.5	148.5
Ludhiana, Punjab	Rice-wheat	13.2	59.7	Maize-potato-onion	27.9	125.0
				Groundnut-potato-bajra(F)	23.3	111.8
Modipuram ,Uttar Pradesh	Rice-wheat	12.9	32.2	Maize-potato-sunflower	24.2	68.2
				Rice-wheat-moong	15.9	40.3
Sabour, Bihar	Rice-wheat	11.0	43.0	Rice-potato-onion	29.0	83.7
				Rice-wheat-maize	15.7	54.1
Bhubaneswar, Odhisha	Rice-rice	6.7	41.3	Rice-maize-cowpea	17.4	69.0
				Rice-maize-greengram	14.8	50.8
Coimbatore, Tamil Nadu	Cotton-sorghum-fingermillet	4.1	48.2	Beet root-greengram-maize+cowpea	7.1	93.1
				Chillies+onion-Sunhemp-okra+coriander	6.6	85.2
Thanjavur, Tamil Nadu	Rice-rice-sesame	13.7	78.0	Rice-rice-brinjal	18.3	108.2
				DS rice-rice-maize+blackgram	17.4	110.3
S.K. Nagar, Gujarat	Groundnut-wheat-fallow	4.1	65.4	Groundnut-wheat-sesame	7.0	125.1
				Groundnut-onion-greengram	5.0	81.4
Bangalore, Karnataka	Hybrid cotton-sunflower	7.0	12.8	Maize-groundnut	12.2	44.1
				Maize-sunhemp-sunflower	11.3	40.8
Hyderabad, Andhra Pradesh	Rice-rice	7.9	22.9	Maize-onion	12.3	59.6
				Maize-tomato	12.1	48.1
Mean	-	9.2	47.2	-	16.9	85.8

Annexure VII

Percentage increase in net returns as influenced by improved cropping system over existing cropping system.

State	Centre	Existing cropping system (ECS)	Improved cropping system	Net increase in returns over ECS (%)
Bihar	Rajendranagar	Maize - sunflower	Maize + soybean - potato	299
	Sabor	Rice - wheat	Rice – cabbage + coriander - sesamum	89
Gujarat	Junagarh	Ground nut – wheat - fallow	Clusterbean – fennel + garlic – seasame + sorghum	121
	Navsari	Rice - chick pea	Rice – cabbage - green gram	289
Haryana	Hisar	Pearl millet - wheat	Cotton - wheat	27
Jharkhand	Ranchi	Rice - wheat	Rice – potato - green gram	72
Karnataka	Kathalgere	Rice – fallow - rice	Rice – fallow - groundnut	32
	Shirguppa	Rice - rice	Rice + susbania – fallow - ridge gaurd	65
Kerala	Karamana	Rice – rice - fallow	Rice + fish – rice + fish - culinary melon	1885
Madhya Pradesh	Jabalpur	Rice - wheat	Rice – onion - green gram	114
	Powerkheda	Soybean - wheat	Soybean – potato - fodder	446
Maharashtra	Karjat	Rice - groundnut	Rice - brinjal	64
	Parbhani	Soybean - sorghum	Maize + soybean + sesbenia – chickpea + wheat – cowpea + okra	90
Odisha	Bhubaneswar	Rice (HYV) – groundnut - fallow	Rice (HYV) – maize + radish – okra + amaranthus	226
	Chiplima	Rice – groundnut - fallow	Rice – maize + coriander – cowpea + amaranthus	91
Punjab	Ludhiana	Rice - wheat	Maize + cowpea + sesbenia – gram + gobhisarson - summer moong	186
Rajasthan	Jaipur	Pearl millet - wheat	Green gram - mustard	94
	Kota	Soybean - wheat	Soybean + red gram – oat - summer mungbean	66
Tamil Nadu	Thanjavour	Sunhemp (GM) –rice - black gram (relay crop)	Sunhemp (GM) – rice + dhaincha (10:1) - okra (R&F)	25
Telangana	Rudrur	Rice - rice	Maize + soybean - tomato	619
Uttar Pradesh	Faizabad	Rice - wheat	Rice- potato - green gram	264
	Kanpur	Rice - wheat	Maize - garlic	357
Uttarakhand	Pantnagar	Rice - wheat	Rice – potato - cow pea	197
West Bengal	Durgapura	Pearl millet - wheat	Clusterbean - mustard	94