rate and operating pressure and it is important that pump characteristics and operating conditions need to be set by technical personnel.

Fig. 4. Commonly available portable pumpsets in Indian market

Selection of portable pumpsets

It is commonly believed that portable pumpsets are suitable only for furrow irrigation and not for sprinkler. In market there is wide range of sprinklers available for pressurized irrigation. The common sprinklers used by the farmers are raiser type sprinklers where working pressure is 2-2.5 kg/cm^2. Testing and standardization of operational parameters of sprinklers on portable pumspet need to be evaluated before recommending it for use.

In Indian market, portable pumpsets of 1.5-2.0 hp size operating on petrol or kerosene are available on large scale. Petrol-start-diesel-run pumpsets of 1.5 hp can be chosen as it is easily available and cost effective compared to petrol. Detailed specifications of selected portable pump sets is given below,

1. Engine Model : HSMF, MK-12
2. Make : Greaves Cotton Ltd, Chennai
3. Rated RPM : 3000 rpm
4. Rated Power : 1.5 hp
5. Fuel : Petrol start & Diesel run
6. Pump : 2” X 2” Monoblock
7. Pressure Head : 12 meter
8. Discharge : 5 lps (liters per seconds)
9. Pumpset weight : 34 kg

Fig. 5. Portable diesel pumpset of 1.5 hp

Feasibility tests of portable pumpset for sprinkler

Several tests and demonstrations of portable pumpset along with sprinklers were studied for lifting of water from pond and its distribution at CRIDA research farm. In various cases, about one thousand cubic meter of water from farm pond was lifted and used for supplemental irrigation with different irrigation methods such as furrow, sprinklers and pipes. The vegetable crops like brinjal, tomato etc were raised in the vicinity of the pond (Fig. 6 and 7).

Fig. 6. Lifting of water through portable pump set and irrigation to crops near by pond

Fig. 7. Lifting of water through portable pump set and irrigation to crops 130 m away from pond

Performance evaluation

In the performance study, no difference was observed in performance of sprinklers operating at either closer of pond or as far as 50 m away from the pond. However, performance may be reduced in undulating fields due to loss in pressure head. During the test it was also observed that required working pressure of test sprinkler was 2.5 kg/cm^2 but actual pressure observed at delivery side was 1.5 kg/cm^2. It indicated that pressure head provided by portable pumpset are not sufficient to give good output of sprinklers. Secondly, though rated speed of the engine was 3000 rpm (as mentioned in specifications) the actual operating speed was 2000 rpm. For these operating conditions, the performance of pumpset was found to be satisfactory. The details of sprinkler performance, area coverage and fuel cost is given in Table 1.

Table 1. Performance test of portable pump sets for sprinkler irrigation

Sr. No.	Particulars	Observations
1.	Engine speed, rpm	2000
2.	No. of sprinklers	06
3.	Sprinkler spacing, m	12
4.	Radius of spray obtained, m	10
5.	Net Area Irrigated, m^2	714
6.	Discharge at delivery, m^3/hr	09
7.	Irrigation yield, mm/hr	10 mm
8	Fuel consumption, l/hr	0.686
9,	Fuel cost for irrigation (10 mm), Rs/acre	160

The spray radius of the each sprinkler was found to be 10 m compared to 12 m with working pressure of 3 kg/cm^2 as in 5 hp pumpset. Although, there was reduction in spray radius of 18% the saving in fuel cost was about 50% when compared with pumpset of higher horsepower. Hence, water lifting from pond with portable pumpset and irrigation through sprinkler was found to be satisfactory. Using identified pumpset, six sprinklers can be operated at a time covering an area about 700 m^2. Total cost of fuel was 160 Rs/acre for 10 mm irrigation. Study showed that one acre area can be irrigated in a day using portable pumpset. In brief, portable pumpset are suitable for small-scale irrigation using sprinkler as improved method. Moreover, its overall weight is 34 kg, improving maneuverability. There is a further scope to improve upon portability of this pumpset by selecting appropriate material and reduce the weight. In this context, nylon pump was developed which could able to reduce overall weight of the pump by 10 kg. A portable pumpset with newly developed nylon pump is shown in Fig 8. The performance of nylon pump is on par with existing cast iron pump.

Fig. 8. Portable pumpset with nylon pump

Economics of portable diesel pumpset

The economics of portable diesel pumpset of 1.5 hp with different irrigation methods for irrigation of 50 m^3/acre is worked out and the same is given in Table 2. In many parts of India mainly Orisa, Coastal AP, West Bengal etc farmers use portable pumpset to lift water from shallow dugouts and ponds and irrigate vegetables with half inch pipe. This is common practice for small scale irrigation. The economics of traditionally practiced irrigation method is compared with furrow irrigation and sprinkler as improved method.

Table 2. Economics of identified portable pumpset with different irrigation methods for 50 m^3/acre

Irrigation Method	Flow rate (m^3/hr)	Operation (hrs)	Fuel (l)	Fuel cost* (Rs)	Labour Cost* (Rs)	Total Cost, (Rs)
Pipes(1/2")	2	25	17	714	600	1314
Furrow	14	3.5	2.4	100	750	850
Sprinkler	8	6	4	168	300	468

*Diesel@42 Rs/l and labour @ 150 Rs/day

The economic analysis for operation of identified diesel pump with different irrigation methods showed that the cost of sprinkler irrigation is 55% lower than that of furrow irrigation and 35 % of pipe irrigation. Consumption of fuel is higher with pipe irrigation and hence operational cost is higher. In case of furrow irrigation though fuel consumption per unit of delivery was relatively less but cost of labour was high due to more number of persons involved. Moreover, water use efficiency of furrow irrigation is lower than sprinkler. Overall, sprinkler irrigation is superior to furrow and pipe method of irrigation as it is cost effective and water use efficient.

Up-scaling of portable pumpset for farm pond water use – A case study

After conducting several tests portable pumpset technology along with sprinkler set it was up-scaled in Adilabad district of Telangana for efficient use of farm pond water. Based on interest of farmers, construction of farm ponds was undertaken at identified locations. In total, thirty ponds were constructed in project area (National Agriculture Innovative Project during 2008-12) with the help of District Water Management Agency (DWMA). The average capacity of each pond was about 1000-1200 m^3. The ponds constructed under MGNREGA were also taken for improvement as depth of pond constructed under scheme was only 2 m. These ponds were remodeled from 11 x 9 x 2 meter to 20 x 20 x4.5 m by employing machines as it is difficult to dig beyond 2.0 m manually. Typical pond constructed is shown in Fig 9.

Fig. 9. Farm pond on farmers field

A strategy was worked out to utilize farm pond water for small scale irrigation. A user group was formed of nine interested farmers and were distributed with 9 portable pumpsets and accessories including pipes among them. These pumpsets were demonstrated and accordingly training were imparted to the selected farmers to let farmers to understand the operating principle of portable pumpset. The portable pumpsets were operationalized at farmers' field for pressurized irrigation for supplemental irrigation and to raise vegetable crops (Fig 10).

Fig. 10. Portable pumpset in operation on farmers' field

Impact of farm pond water use with portable pumpset

Water harvesting technology and utilization of harvested water through portable pumpset made a significant contribution in increasing crop yield and income of farmers by extending crop growing period and cropping intensity. Usually, last picking of cotton is being taken in mid January but because of water availability and appropriate size of pump farmers could able to provide 2 to 3 supplemental irrigations and harvested two extra pickings. The farmers earned extra income due to increase in productivity of rainfed crops and cropping intensity by growing vegetable crops. The average increase in cotton yield due to supplemental irrigation is 1.5 quintal per acre. Area irrigated, number of supplemental irrigation, operational cost for irrigation, yield increased and additional returns of beneficiary farmers are given in Table 3. The pay back for farmer's contribution was found to be only one or two seasons. One of the farmers raised *rabi* sorghum for grain and fodder production. In addition to utilization of harvested water for supplemental irrigation, it was also made available for drinking purpose particularly for cattle.

Table 3. Income from supplemental irrigation using portable pumpset

Name of the farmer	Crop	No. of SI	Operational cost (Rs/acre)	Increase in yield (q/ac)	Additional return, Rs/ac
Shri. E. Mallesh	Cotton (1 ac)	2	750	1.5	6000
Shri. Ganga Reddy	Cotton (1 ac)	3	1125	1.5	6000
Shri K. Ramarao	Cotton (1 ac)	3	1125	2.0	8000
Shri S. Bheem Rao	Cotton (1 ac)	2	750	1.0	4000
Shri. M. Manthu	Sorghum (2 ac)	3	2050	07q grain+ 12 q fodder = Rs 20,000/	
Shri. N. Rajanna	Vegetables (0.5 ac)	2	750	--	6800
Shri. K. Ramarao	Vegetables (0.5 ac)	3	1125	-	9200

Lesson learnt

Although portable pumpsets are energy efficient for lifting pond water, the farmers experienced some operational difficulty in existing pumpset such as cranking with rope, start-to-run plug, chock direction, etc. However, some minor technical improvements are needed in the existing pumpset to match farmer's aspirations.

Conclusions

Water harvesting through farm pond is a viable technology but appropriate lifting mechanism is required for effective use of pond water in agriculture. A portable pumpset of 1.5 hp was tested for lifting of pond water and pressurized irrigation showed satisfactory performance in terms of both cost and energy. The utilization of harvested water using portable pumpset added significant contribution to farmer's income. The payback period of portable pumpset is just one year. Portable technology inspired the farmers to make effective use of harvested water.

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Conservation Agriculture in Rainfed Systems

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The biggest challenge in 21st century is to produce the food and feed for the growing population and livestock from decreasing per capita land availability without environmental degradation. India has the largest irrigated area in the world, but still 60 percent of its cropped area is rainfed and it contributes substantially to the production of coarse cereals, pulses, and oilseeds. But the state of rainfed agriculture is precarious and the problems associated with it are multifarious. The most significant are: high yield fluctuations mainly due to aberrant weather, often much behind the risk bearing capacity of the farmers which led to poor adoption of modern technology, low cropping intensity; land degradation and the high incidence of rural poverty. To increase the crop productivity and meet the growing demands of the food production with improved agronomic practices such as intensive tillage, indiscriminate use of fertilizers, improved crop protection through use of pesticides and burning of crop residues for disposing of the residues from the field are being adopted etc.(Ghasemi Mobtaker *et al.,* 2010). These practices are highly productive but albeit at a low level of satisfaction, since these gains were due to massive exploitation of natural resources, resource degradation, highly energy intensive and is significant contributor to global warming. Its share to total greenhouse gas (GHG) emission is about 10-12% and this is expected to increase with increase in demand for agricultural products due to ever growing population. The present tillage based intensive agriculture being practiced is at has already shown negative effect on the quality of natural resources such as soil, water, terrain, biodiversity and the associated ecosystem services provided by nature (Dumansky *et al*., 2014). This is evident from loss of soil organic matter (SOM), accelerated soil erosion, deterioration of soil physical, chemical, and biological health, poor input (water & nutrient) use efficiency, groundwater pollution, declining water tables, salinization and waterlogging, loss of biodiversity and decline in factor productivity.

Hence sustainable agricultural intensification is a must to lift the resource poor farmers out of hunger and poverty and agricultural intensification should focus on achieving food, nutritional, environmental and livelihood security through improvement of farming systems of resource poor small farm holders without harming the environment and conserving natural resources for future generations. There is also a need to enhance the resilience of productions systems to biotic and abiotic stresses, particularly those arising from climate change. The sustainable crop production intensification must not only reduce the impact of climate change on crop production, but also mitigate the factors that cause climate change by reducing emissions and by contributing to carbon sequestration in soils.

The United Nations Millennium Development Task Force on hunger has recommended enhancement of agricultural productivity and profitability of resource poor farmers along with conservation of natural resources as one of the five recommendations to fight hunger. In this context, conservation agriculture (CA) holds great promise as the aim of conservation agriculture is agricultural sustainability, conserving, improving and making more efficient use of natural resources through the integrated management of available soil, water and biological resources, combined with judicious use of external inputs. CA has potential to reduce the negative impacts of intensive agriculture by minimizing soil degradation, build up soil organic matter, improve soil physical and biological health; reduce use of fossil fuels and enhance input use efficiency contributing, thereby, reduction of emission of GHGs in the atmosphere. Thus, CA is a base for sustainable agricultural production intensification and complies with the generally accepted ideas of ecological sustainability. According to FAO (FAO, 2014), Conservation Agriculture (CA) is an approach to manage agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. CA is a resource-saving environmental friendly agricultural production strategy that aims to achieve production intensification and high yields while conserving the natural resource base through compliance with following three interrelated principles, viz., minimum soil disturbance, permanent soil cover, crop rotation and controlled traffic along with other good production practices of plant nutrition and pest management (Abrol and Sangar, 2006; Bhan and Behera, 2014).

Conservation agriculture systems require a total paradigm shift from conventional agriculture with regard to management of crops, soil, water, nutrients, weeds, and farm machinery (Sharma *et al*., 2012). Some of the salient features of conservation agriculture vis-à-vis conventional system are given in Table 1.

Table 1. Salient features of conservation agriculture vis-a-vis conventional system

Features	Conventional agriculture	Conservation agriculture
Cultivation	Ecologically unsustainable	Eco-friendly
Tillage	Excessive mechanical tillage	No- till or reduced tillage(biological tillage)
Crop Residue	Burnt or removed (bare surface) or incorporated	*in-situ* surface retention (permanently covered)
Manuring	No manuring/Green manuring (incorporated)	Brown manuring/cover crops (surface retention)
Crop rotations	Mono cropping/culture, less efficient rotations	Diversified rotations involving legumes
Farm operations	Heavy reliance on manual labor, uncertainty of operations	Mechanized operations ensure timeliness of operations. Labour requirements are generally reduced by about 50%. Fuel savings in the order of around 60% or more.

Global scenario of CA

CA/No-till crop production systems are experiencing increasing interest in most countries around the world. There are only few countries where No-tillage is not practiced by at least some farmers and where there are no local research results on the technology available. There is a worldwide adoption of the No-tillage technology of about 45 million ha (Derpsch, 2001). Since then the adoption of the system has continued to grow steadily especially in South America where some countries are using CA on about 70% of the total cultivated area. In the last years an expansion of the area under No-tillage has been reported in Asia, especially in China and Kazakhstan where more than a million ha have been reported in each country. But also in Europe there is progress in the adoption. There are about 650,000 ha of No tillage being practiced in Spain, about 200,000 ha in France and about 200,000 ha in Finland. No-tillage based conservation agriculture systems gain also increasing attention in Africa, especially in Southern and Eastern Africa. In many countries the area is still low due to the high percentage of small scale farmers, but the numbers are increasing steadily as well. Up to now No-tillage has expanded to more than 100 m ha worldwide, showing its adaptability to all kinds of climates, soils and cropping conditions. No-tillage is now being practiced from the arctic circle over the tropics to about 50º latitude South, from sea level to 3000 m altitude, from extremely rainy areas with 2500 mm a year to extremely dry conditions with 250 mm a year. The wide recognition as a truly sustainable farming system should ensure the growth of this technology to areas where adoption is still small as soon as the barriers for its adoption have been overcome. No-tillage is now being practiced by farmers from the arctic circle (e.g. Finland)over the tropics (e.g. Kenya, Uganda) to about 50º latitude South(e.g. Malvinas/Falkland Islands). From sea level in several countries of the world to 3000 m altitude (e.g. Bolivia, Colombia), from extremely dry conditions with 250 mm a year (e.g. Western Australia), to extremely rainy areas with 2000 mm a year (e.g. Brazil) or 3000 mm a year (e.g. Chile).No-tillage is practiced on all kind of farm sizes from half hectare (e.g. China, Zambia) to hundreds of ha in many countries of the world, to thousands of ha (e.g. Australia, Brazil, USA, Kazakhstan). It is practiced on soils that vary from 90% sand (e.g. Australia), to 80% clay (e.g. Brazil's *Oxisols* and *Alfisols*). The widespread adoption also shows that No-tillage cannot any more be considered a temporary fashion, instead the system has established itself as a technology that can no longer be ignored.

CA systems are being adopted in some 147 m ha, largely in the rainfed areas and that the area under CA is increasing rapidly. USA has been the pioneer country in adopting CA systems and currently more than 18 million ha land is under such system. CA practices have now been widely adopted for many years include Australia, Argentina, Brazil and Canada. Conservation agriculture is being adapted to varying degrees in countries of south east Asia viz. Japan, Malaysia, Indonesia, Korea, the Philippines, Taiwan, Sri Lanka and Thailand. Central Asia is another area prospective of CA. In South Asia CA systems would need to reflect the unique elements of intensively cultivated irrigated cropping systems with contrasting edaphic needs, rainfed systems with monosonic climate features, etc. Concerted efforts of Rice-Wheat Consortium for the Indo-Gangetic Plains (IGP) a CG initiative and the national research system of the countries of the region (Bangladesh, India, Nepal and Pakistan) over the past decade or so are now leading to increasing adoption of CA technologies chiefly for sowing wheat crop. According to recent assessments in more than one million ha area wheat was planted using a no-till seed drill in the region.

In India, efforts to adapt and promote resource conservation technologies have been underway for nearly a decade but it is only in the past 4 to 5 years that the technologies are finding rapid acceptance by the farmers. Efforts to develop and spread conservation agriculture have been made through the combined efforts of several State Agricultural Universities, ICAR institutes and the CG promoted, Rice-Wheat Consortium for the Indo-Gangetic Plains. Unlike, in the rest of the world, in India spread of technologies is taking place in the irrigated regions in the Indo-Gangetic plains where rice-wheat cropping system dominates. CA systems have not been tried or promoted in other major agro-eco regions like rainfed semi-arid tropics, the arid regions or the mountain agro-ecosystems.

Resource conservation and Conservation agriculture systems

More often, the conservation agriculture and resource-conserving technologies (RCTs) were used as synonyms. But there is a sharper distinction between these two. All RCTs may not be part of CA systems. The resource conservation technologies may include new varieties that use fertilizers more efficiently, zero or reduced tillage practices that save fuel and improve plot-level water productivity, laser leveling techniques which may save water resources during irrigation, drip irrigation, sprinkler irrigation using rain guns, different land configurations for enhancing in-situ moisture infiltration into the soil etc. However, the term conservation agriculture practices in true sense will only refer to the RCTs with the following characteristics:

- Soil cover, particularly through the retention of crop residues on the soil surface;
- Sensible, profitable rotations; and
- A minimum level of soil movement, e.g., reduced or zero tillage.

The distinction between RCTs and CA is important because some RCTs may be attractive in the near-term, may be unsustainable in the longer-term. An example of this could be the use of zero tillage without residue retention and without suitable crop rotations which, under some circumstances, can be more harmful to agro ecosystem productivity and resource quality than a continuation of conventional tillage practices. Hence, the CA essentially consists of all the three components and it addresses the improved concept of the complete agricultural system to achieve higher productivity and improved resource base. The Food and Agriculture organization (FAO) defined CA with the following quantifying parameters:

Minimal soil disturbance: The disturbed area must be less than 15 cm wide or 25% of the cropped area (whichever is lower): no periodic tillage disturbs a greater area than the aforementioned limits.

Soil cover: Three categories are distinguished between 30-60%, 61-90% and 91%+ ground cover, measured immediately after the planting operation: ground cover less than 30% will not be considered as conservation agriculture. The objective of retention of sufficient residue on the soil surface is to protect the soil from water/wind erosion, water run-off and evaporation to improve water productivity and to enhance soil physical, chemical, and biological properties associated with long-term sustainable productivity;

Crop rotation: The rotation should involve different crops in two kharif .The objective is to employ economically viable, diversified crop rotations to help moderate/mitigate possible weeds, disease, and pest problems. Conservation agriculture has been promoted as an agricultural practice that increases agricultural sustainability, concomitant with a potential to mitigating greenhouse gas emissions (Paustian *et al*., 1997; Schlesinger, 1999). There are, however, contrasting reports on the potential of conservation agriculture practices for C sequestration (Blanco canqui and Lal, 2008).

Advantages and disadvantages

Conservation agriculture is generally a "win-win" situation for both farmers and the environment (Hobbs *et al*. 2006). The proponents of CA invariably highlight its many advantages, while the opponents focus on the disadvantages. The statement about advantages and disadvantages of CA are often appropriate because regional issues such as climate, soil type, farming system, farmer knowledge and availability of resources can have a major impact on crop yield. For example, improper CA seeding equipment or its application can result in lower yields with CA compared to conventional tillage (CT) due to poor crop stand and establishment. While in other regions the use of appropriate seeding methods can lead to significant yield benefits.

Resource conservation

- Increase in rainwater use efficiency.
- Improves soil structure, reduces soil crusting, moderates soil temperature
- Increase soil moisture (due to increased rain water infiltration, water holding capacity and reduced evaporation loss)
- Facilitates recycling and availability of plant nutrients
- Weed growth
- Helps build up soil organic matter in the surface layers
- Improves biological activities/processes with abundant and diverse community of beneficial soil biota and associated eco system services

- Due to controlled traffic, no compaction in crop area. Compaction only in tramline,
- Advancement of sowing
- Improves carbon sequestration in the soils

Economic benefits

- CA technologies may have yield advantage up to 50%.
- Reduces cost of production by Rs. 2,000 to 3,000 ($ 33 to 50)/ha by savings on diesel, labour, energy and inputs (water, fertilizers, pesticides, herbicides) costs.
- Labour requirements are generally reduced by about 50%.
- Fuel savings in the order of around 60% or more.
- Impart greater resilience to biotic and abiotic stresses including climate change related aberrations, thus, lowering the risk of crop failure/yield losses.
- Increase in water use efficiency thereby, saves water up to 20% – 30%
- Offers opportunities for crop diversification involving agroforestry to enhance natural ecological process and ecosystem services.

Environmental benefits

- CA is environmentally friendly and no tillage (NT), which is the most extreme forms of CA, requires less fuel resulting in lower carbon dioxide emissions, one of the gases responsible for global warming
- Reduces soil erosion / degradation.
- Improves water quality due to reduced contamination levels from agrochemicals and soil erosion.
- Helps to sequester carbon in soil at a rate ranging from about 0.2 to 1.0 t/ha/year or more
- Eliminate burning of crop residue which contributes to greenhouse gas emission, air pollution besides loss of plant nutrients.
- Mitigate Green House Gas emissions and improves environmental sustainability.
- Reduces energy consumption

Disadvantage

Disadvantage of Zero tillage is that the non-mobile, yield limiting nutrient such as phosphorus is not easily incorporated into the soil, with ZT implementation, a proper seed drill for mechanical or manual nutrient placement along with seeding can overcome growth restrictions. Further, nutrient limitation may disappear with the improved top soil fertility that eventually results from ZT. Besides this introduction of legumes improve the nutrient cycle. Some authors suggest the rotation of high and low residue producing crops to help maintain the optimum amount of residue in the system.

Challenges and strategies to overcome the challenges in adoption of CA in rainfed agriculture

The adoption of CA is common under rainfed conditions in other countries is high But in India the adoption of CA is very low. There are some constraints in adoption of CA for many small farmers in rainfed agriculture**.**

Lack of proper machinery

One of the major constraints in adoption of conservation agriculture is the availability of suitable cost effective equipments affordable by farmers. Heavy implements and large tractors may not be required for implementation of CA. Small tractor operated machinery manually, Animal power drawn or low horsepower 2 and 4 wheel tractors can be used as they easily be adopted by small and marginal farmers. A strip-till system where a rotary blade cuts the residue and forms a narrow strip for planting seed and fertilizer can be tried as an attachment for 2 wheel tractors for this purpose. Many small machinery were developed in India under rainfed regions.

Permanent retention of in situ crop residues is a pre-requisite and an integral part of conservation agriculture. In dryland eco-systems, availability of crop residues is a major problem since moisture stress is common, hence crop yields and residue production are low, besides low production residues have competing uses (e.g. fodder, fuel or construction material). Crop residues, particularly cereal stover, provide high value fodder for livestock in smallholder farming systems in rainfed agriculture. Indeed, feed is often in critically short supply, given typical small farm sizes, and limited common lands for grazing.

Termite attack**:** Besides the production and competing demands for crop residues termite attack on the residue is also a major issue in rainfed regions. Due to termite attack the residue cover is not seen on the surface. The termite attack can be minimized with application of Chlorpyrifos. Anchored residues reduce the termite attack to a great extent as compared to flat residues.

Weed management: One of the major challenges perceived for low adoption of CA in rainfed regions of developing countries by the farmers is crop weed competition and weed management. The benefits of CA systems in irrigated regions in general and rainfed regions in particular may be offset by heavy weed infestation, shifts in weed communities Weed infestation during and between two crop seasons are very high. The tillage and residue management are crucial factors determining the species diversity. Substantial shift in the weed flora of crop lands from easy to control annual weed species to perennial weeds which are difficult to control, broad leaved weeds to grasses since the annual broadleaf species adapt better to frequently disturbed habitats or changes in the rank order of weeds occurrence are observed. Moreover larger weed diversity is observed with tillage which prevents the domination of a few awkward weeds hence the weed control options also differ. Furthermore, it was observed that smaller and more diverse weed communities in conventionally tilled than in minimum tilled plots. Hence the weed species present will be an expression of both management and the environment. However the reports on weed shift with tillage systems are inconsistent. The shift in weed population may affect competitive interactions between crops and weeds and also the crop growth and productivity which is a major reason for non adoption of CA system by the growers. A major criticism of CA is its enhanced reliance on herbicides as compared to tilled systems. In particular, glyphosate may be heavily used, especially to control perennial weeds. Lack of availability of certain herbicides and knowledge about its proper use. Moreover, the efficacy of herbicides in rainfed regions depend on the weather conditions specifically quantity and timing of rainfall, can significantly impact the efficacy of individual pre emergence (PRE) and post emergence (POST) herbicides. The lower efficacy of herbicides in rainfed regions is due to poor soil moisture conditions and uncertain rainfall is observed. For pre emergence herbicides like pendimethalin optimum soil moisture through precipitation is required within 7 - 14 days after application to dissolve the herbicide in soil water solution so that it can be taken up by the emerging weeds after germination. In adequate or delayed precipitation can reduce herbicide effectiveness and decrease weed control. Depending on soil type, higher quantity of precipitation (*i.e.* greater than 25 mm), especially within 24 hrs after application, can cause herbicides to leach through the soil profile and consequently reduce efficacy. However the grower has an opportunity for post emergence herbicide application. But, timing of post emergence herbicide application with weed size is critical, if weeds become too large due to continuous rains then control can be reduced. While most post emergence herbicides require no precipitation for several hours after application to ensure that movement across the leaf membrane can occur. Hence farmers need effective and economical alternative weed management strategies. Considering these challenge of weed control and herbicide resistance of weeds in CA, integrated weed management options with cautious use of herbicides is proposed as the 4th pillar of CA. Use of single herbicide without rotation may create weed resistance to herbicide and shift in weed population (increase in broad leaf weeds) and lead to increase in total number of weeds. Hence CA systems would require early and more frequent weeding that is likely to worsen existing labor bottlenecks in smallholder crop production systems of developing countries. Hence for adoption of CA by smallholder farmers, there is need for identification of economically feasible integrated weed management practices *i.e* use of herbicides in combination with mechanical hoe weeding to reduce the weed density over time. Moreover the integration of existing strategies like mechanical methods, herbicide rotation and development of new techniques like allelopathy, crop nutrition may be the effective modern weed management tools in CA and are required to reduce herbicide resistance, weed shift and sustain the crop productivity in CA and global food security in long run. These improved good and effective weed management practices which aim at effective weed control depletes the weed seed bank and also reduces the species richness.

***Compaction**:* There are reports of increasing bulk densities under CA particularly when soils are wet and more prone to compaction. However, this can be minimized if farm operations are carried out manually or using animal/low powered tractor and/or by controlling traffic farming. Infiltration of water in CA systems is greater than in conventionally tilled plots as long as ZT is combined with residue cover due to greater earthworm activity facilitating biological tillage.

Social barriers: The mindset of a large group of farmers on tillage, apprehension of lower crop yields and/or economic returns, negative attitudes or perceptions, and institutional constraints about zero tillage are the possible reasons for limited adoption and diffusion of the technology by the farmers

Skills and knowledge barrier**:** The site specific knowledge on components of CA practices, and understanding of basic processes and component interactions of CA is required for the spread of CA system. But this knowledge is limited since conservation agriculture systems are much more complex than conventional systems and site specific. This learning process will accelerate building a knowledge base for sustainable resource management.

Fourth Principle required to define CA for higher yields and resource conservation

Conservation Agriculture is commonly defined around a set of three principles. The previous studies pertaining to comparing the effect of NT/RT relative to CT, and their effect in relation to rainfall and duration of the experiment has revealed that the yield decline in NT/RT was significantly greater in dry climates (11%) than that in humid climates (3%) irrespective of duration of the experiment. However, in humid climates, the decline in yield was only significant for long term NT/RT implementation (6%), whereas in dry climates, the decline was only significant in short term (12%). These studies indicated that the major limitation for success of CA is the availability of soil moisture. The past studies have indicated that insitu moisture conservation increased the yields to a tune of 10 to 20 % by conserving soil moisture and reducing soil loss. Hence implementing moisture conservation technologies like in-situ moisture conservation practices in line with the CA principles increases crop yields along with resource conservation. The crop residues/mulch helps in improving the physical conditions of the topsoil which are conducive for seed germination, reduces weed growth, and improves the crop growth. But a number of important constraints exist to widespread adoption of CA. The lack of crop residues to provide sufficient surface mulch consistently ranks amongst the top constraints especially in areas with high livestock feed requirements. Zero or minimum tillage without crop residues usually results in lower yields, partly because poor crop residue/ mulch increases the runoff and reduces soil moisture notably in drier climates. Hence strategies for promoting CA would need to change, the fourth principle can be considered for successful implementation of CA.

Integration of *in-situ* moisture conservation practices as fourth principle in CA has potential to reduce substantially the degree of soil erosion, as well to increase the farmer's income by increasing grain yields and reducing production costs. Appropriate use of fertilizer and additional dose of fertilizer is required to be defined in CA to enhance both crop productivity and produce. The threshold limits for adequacy of crop residues to ensure soil cover under smallholder conditions under rainfed conditions also need to be worked out. Integrated weed management may be another component that is crucial for successful implementation of CA. This is because weeds have been highlighted as one of the most difficult management issues within this system in a number of regions.

Strategies to overcome challenges

Strategies to increase residue retention

In rainfed agriculture, moisture stress is common, moreover, the rainfall is unimodal and erratic with high variability both within and between seasons, and droughts are common, due to which the crop yields and residue production are low. Besides low residue production, competing uses for crop residues also exist (e.g. fodder, fuel or construction material). In the tropical rainfed regions, crop and livestock production are closely integrated in mixed smallholder farming systems. Crop residues, particularly cereal stover, provides high value fodder for livestock in smallholder farming systems in rainfed agriculture. Indeed, feed is often in critically short supply, especially under typical small farm sizes, and limited common lands for grazing.

In these situations where competition for crop residue use is strong, intercropping with grain legumes can be a viable strategy to achieve surface cover because the legume will cover the area between rows of the main crop and help conserve moisture. Apart from this manipulation of harvest height of the crop increase the residues in case of cereals like maize and sorghum the crops can be harvested at 60 cm since the crop residue above 60 cm is nutritious and 30 cm height for crops like pigeonpea and castor (Pratibha *et al.,* 2015). Legumes like horsegram (*Macrotyloma uniflorum*) can be grown if the rainfall is around 70 mm between October - December **.**

Alley cropping is one innovation in rainfed areas that offers productivity, economic and environmental benefits to producers. Different agroforestry models along with CA is an important viable option to augment biomass supply particularly in rainfed arid and semi arid regions. Intercrops or cover crops with legumes can be sown in between widely spaced tree species (Table 2).

Table 2. Sources of biomass production		
Biomass source	**Qty of Biomass (kg/acre/yr)**	**Remarks**
Biomass produced at farm level		
Gliricidia /*Cassia Siamea* (200acre)	15,000	30kgs/plant/year- from 5th year planted on bunds and around compost pits after planting (three loppings)
Sun hemp on bunds	1750	1.3 kg/ m^2 total area of bunds per acre is 560 m^2 (100m×40m) and 2m wide bunds
Weeds	2000	
Crop residue	2500	
Neem trees on farm (min-3)	2000	300 kgs per tree per year (2 loppings)
Pongamia trees on farm (min-3)	2000	300 kgs per tree per year (2 loppings)

Integration of *in-situ* moisture conservation practice as IV principle

***Bed and furrow method*:** In bed planting, 100 cm wide beds and furrows of 35 cm width and 15-20 cm depth are prepared with the help of bed planter. After preparing the fresh beds, during the first year, these beds can be kept as permanent beds for subsequent year with the retention of crop residue, and reshape the beds, if required, during the sowing of the next crop. Depending on the spacing 2-3 rows of crops, can be sown on the beds. This technology can be used both in irrigated and rainfed conditions. A permanent bed planter was fabricated by CRIDA for rainfed agriculture. The implement can do three operations simultaneously i.e reshaping of the bed, sowing and fertilizer application. Permanent bed under rainfed conditions has several advantages such as it helps in timely sowing of the crop, requires low fuel and labour costs, improves soil health and quality, reduces erosion and conserve soil moisture with higher water use efficiency (15-20%) and yield enhancement. In permanent bed and furrow planting the furrow acts as a drainage channel in high rain fall/waterlogged areas and provides better microclimate for plant growth and root development.And as a conservation furrow in low rainfall areas.

Permanent conservation furrow

In this method a the crops like maize and pigeon pea are sown and a conservation furrow of 45 cm wide and 20 cm deep is made. This furrow saves around 250 m^3 water can be conserved. This furrow is reshaped every year. The inter spaces between two pairs can be effectively utilized by sowing legume crops.

Role of conservation agriculture on sustainable intensification

Sustainable intensification involves increasing output levels from the same area of land with low negative environmental impacts of agricultural production. CA fits within the sustainable intensification paradigm of producing more from less purchased inputs as conservation agriculture offers an opportunity for arresting and reversing the downward spiral of resource degradation, decreasing cultivation costs and making agriculture more resource–use-efficient, competitive and sustainable. In addition to the obvious conservation of resources there are also significant environmental benefits of zero or minimum till systems. "Conserving resources-enhancing productivity" is the mission of CA. Traditional agricultural practices involve tilling up soils to remove weeds, shape the soils into rows for planting, and creating furrows for irrigation. Tilling the soil has adverse effects such as contributing to soil erosion, soil compaction, the loss of organic matter (including the release of carbon into the atmosphere), and the degradation of soil aggregates. Whereas CA (Zero tillage with residues) reduces the soil compaction and erosion. Hence these practices have the potential of increasing agricultural yields and raising profits for farmers especially in wheat in rice - wheat cropping systems. Besides increasing crop productivity conservation agricultural practices increases the water use efficiency, reducing the weed seed germination, growth, and evaporation and soil erosion. Despite of several advantages the straw is burnt mostly in IGP regions to facilitate land preparation or sowing due to lack of proper implement to sow in the residue. Gupta *et al.,* (2004) estimated that the burning of one ton of straw releases 3 kg particulate matters 60 kg CO, 1460 kg CO_2, 199 kg ash and 2kg SO_2. With the introduction of CA practices with new drills, which are able to cut through crop residue, for zero-tillage planting, burning of straw can be avoided, which is around 10 tons per hectare, which reduces the release of around 13–14 tons of carbon dioxide. Hence recycling of residues without burning on just 5 million hectares would reduce the yearly CO_2 emissions by 43.3 million tons (including 0.8 million ton CO_2 produced upon burning of fossil fuel in tillage). Apart from this zero-tillage on an average saves about 60 l of fuel per hectare thus reducing emission of CO_2 by 156 kg per hectare per year (Grace *et al*., 2003; Gupta *et al*., 2004). Methane is produced during rice cultivation due to anaerobic decomposition of organic matter. Adoption of RCTs would favor the decrease of this GHG. The experiments carried out in different experiments on different methods of rice planting has indicated that Double no till system in rice – wheat system increased the yield and economics of the rice- wheat system. (Akther *et al.,* 2015). Conservation agriculture studies carried out by the different Institutes of the Indian Council of Agricultural Research and the State Agricultural Universities that no-tillage and direct seeding results in saving in time, fuel and helps in adaptation and mitigation of climate change by reducing the GWP (Table 3)(Pratibha *et al*., 2015).The CA practices also improves soil quality and reduces soil erosion.

Table 3. Effect of conservation agriculture practices on NGWP and GHGI in pigeon pea-castor system in rainfed regions

	Tillage	Pigeon pea				Castor			
Tillage	**Residue (cm)**	**NGWP crop**	**NGWP soil**	**GHGI crop**	**GHGI soil**	**NGWP crop**	**NGWP soil**	**GHGI crop**	**GHGI soil**
CT	0	337	1026	0.32	0.97	1109	1082	0.58	0.57
	10	-596	296	-0.47	0.23	-188	265	-0.09	0.13
	30	-3368	-149	-2.7	-0.12	-1663	62	-0.77	0.03
RT	0	-444	243	-0.41	0.22	580	382	0.32	-0.21
	10	-436	-582	-0.37	-0.50	-367	-397	-0.18	-0.19
	30	-2588	-752	-2.1	-0.60	-1543	-721	-0.76	-0.35
ZT	0	289	-167	0.33	-0.19	373	-97	0.23	-0.06
	10	-230	-1220	0.22	-1.17	-417	-1120	-0.24	-0.65
	30	-1502	-1380	-1.5	-1.38	-541	-1907	-0.36	-1.2

(Source: Pratibha *et al.,* 2016)

The typical adoption process for new technologies in general and CA practices in particular follows an 'S' curve, with a relatively slow start to adoption, possibly preceded by farmers' own trials on just parts of CA principles and/or parts of their land, leading then into fast or even exponential growth, and slowing towards a plateau. For farmers to take the leading role in implementing CA, there is a need for policies that encourage knowledge sharing amongst stakeholders at all levels.

CA is relatively new therefore problems can arise for which locally based experience and knowledge does not exist. Since farmers are ingenious in problem solving, and if they pick up the conceptual part of CA, they often innovate and adapt the practices to their own conditions hence practical knowledge and learning system for CA should be built up in the farming, extension and research community and should always be demonstrated to stakeholders as evidence of relevance and feasibility, and used for hands-on training students, researchers, extension agents and farmers as well as sensitizing institution leaders and decision makers. Besides this field days study visits and operational research may be conducted to the successful farms.

Conclusions

The yield in zero tillage were lower in rainfed conditions mainly due to lack of residues and poor soil moisture content. Hence under rainfed regions the yield under CA can be improved with integration of insitu soil moisture as fourth principle. Incentives for abandoning the plough still exist through savings in fuel, labour, and wear and tear of farm implements; low energy input and carbon foot print. In spite of positive socio-economic and environmental impacts of conservation tillage, adoption of conservation tillage is still limited. The main reason for this low adoption is initial higher investment in new machinery and lack of knowledge about crop rotation. Interactions between the components of conservation agriculture and their effects on crop yields are complex and often site-specific and long-term experiments are necessary to provide a better understanding.

Way forward

CA is a complex suite of 'new' resource efficient technologies. However, more research is needed to further improve its adoption

Research

Many factors influence crops yields under conservation agriculture (CA) to conventional tillage (CT). Hence research on development of complete site-specific package of practices is needed based on intensive research.

➢ The research should include the interaction of the key CA components permanent residue cover, minimal soil disturbance, crop rotations to evaluate their effects under local conditions.

➢ The studies should include quantitative assessments of type and amount of crop residue, soil conditions as well as level of soil disturbance.

➢ Breeding for crop varieties adapted to CA conditions may also be beneficial. For example, crop varieties resistant to residue-borne diseases, with a high litter degradation rate or that could grow vigorously in unploughed soil would be valuable.

➢ Development of weed resistance to herbicides is a serious and escalating problem for many CA farmers worldwide, with the use of herbicide tolerant (HT) crops. The major research effort in this area should be towards development of economically viable strategies to prevent and manage weeds and herbicide resistance.

➢ The particular challenge in agriculture in recent times is to identify agricultural practices which ensure stable and productive food supply combined with food of low greenhouse gas intensity.

➢ There is a necessity to quantify crop residue trade-offs and to explore alternatives to overcome them.

➢ Inter disciplinary R & D efforts are required to develop appropriate implements for seeding in zero tillage, residue incorporation and inter-cultural operations.

- ➢ Focus on Modeling of tillage dynamics and root growth, incorporation of soil physical properties in crop growth simulation models and relating it to crop yields under major cropping sequences.
- ➢ Low tillage, crop rotation, cover crops, maintenance of residues on the surface, control of weeds through herbicides, are the key components of conservation farming. Therefore, it is essential that these themes must be studied in depth under diverse soil and climatic conditions across the country on long term basis.
- ➢ Defining appropriate fertilizer practices for CA since fertilizer use efficiency will be affected by the other three principles of CA.

Policies and strategic issues

- ➢ Participatory research and demonstration trials are required to create awareness about the importance of soil resources, organic matter build up in soil. Awareness on these issues will accelerate adoption of CA.
- ➢ Economic incentive and motivations for smallholder farmers to compensate on the yield reduction.

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How ICT Enhance Farmer's Income in Dryland Agriculture

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Agriculture sector has a big contribution in the economic development of India. A large population in India depends on agriculture to fulfill their livelihood. Indian agriculture put in 16% of the overall GDP and gives up the employment to approximately 52% of the population (farmer.gov.in). India occupies the second highest position worldwide in the farm output. Agriculture in India is blessed with a variety of pros such as wider cultivable land, 20 agro-climatic regions, 46 soil types, sufficient agribusiness system and suitable seasons for different crops (A tuli). Indian agriculture is largely dependent on the natural resources and conducive weather conditions. Ever since people have grown crops, livestock and fish, they have sought information from one another. Therefore, accurate and timely information is vital to the agricultural processes (Harjinder).

Information has always been a component of growth and development in human life. Robert Kiyossaki says, "Did you know that lack of information is the number one barrier to wealth?" if so, how should it be communicated to realize available information on agricultural technologies/opportunities in terms of income for the farmer. Communication has been taking the role of connecting people and sharing/exchanging information among the human beings. Communication is one of the most pervasive human activities and it has become ever more widespread due to emergence of new technologies. "Information Communication" means communication of Information. Information and communication technology (ICT) has always mattered in agriculture. Today, ICT represents a tremendous opportunity for rural populations to improve productivity, to enhance food and nutrition security, to access markets, and to find employment opportunities. ICT has unleashed incredible potential to improve agriculture, and it has found a foothold even in poor smallholder farms. ICT supports farmers, agriculture decision makers, and development partners. ICT interventions help in giving practical guide to understanding current trends, implementing appropriate interventions in agricultural programs. Communicating information is not new concept. All India Radio and Television aired agricultural programs since their inception, but gave information in its own time. In present times the relevant and timely information is essential on demand. Small information makes big difference in farmer's life at the time of critical crops growing, harvesting and marketing stages. To reach farmer in these stages, key components are network connectivity between farmer and content provider, receiving devices and interface to access the information.

Communication infrastructure in India

Village level network connectivity for communication**:** India has a very large rural-urban digital divide. Urban India is almost completely covered, both through voice and Internet. Rural India has 2.5 lakhs village offices named as gram panchayats (GPs), which roughly covers about 6.4 lakhs villages. As on today 2.3 lakhs km of pipe has been laid and 2 lakhs km optical fiber cable has been laid to cover around one lakhs gram panchayats. In Gigabit Passive Optical Network (GPON) program, 2.5 lakhs gram panchayats are planned to network connectivity by end of year 2018.

Institutional level network connectivity: National Knowledge Network (NKN) project is aimed at establishing a strong and robust Indian network, which will be capable of providing secure and reliable connectivity. Globally, frontier research and innovation are shifting towards multidisciplinary and collaborative paradigm and require substantial communication and computational power. In India, NKN with its multi-gigabit capability aims to connect all universities, research institutions, libraries, laboratories, healthcare and agricultural institutions across the country to address such paradigm shift. The network design is based on a proactive approach that takes into account the future requirements and new possibilities that this infrastructure may unfold, both in terms of usage and perceived benefits. This will bring about a knowledge revolution that will be instrumental in transforming society and promoting inclusive growth. The target users for the NKN are all institutions engaged in the generation and dissemination of knowledge in various areas, such as research laboratories, universities and other institutions of higher learning, including professional institutions. NKN has already connected over 1648 institutions under various categories throughout the country (nkn.gov.in).

India to remain the fastest growing Internet destination

India's Internet user base has already surpassed the US, and today is second largest after China. Globally, the number of Internet users is expected to touch 4,170 million by 2020, growing at a CAGR of ~6%, and adding ~960 million in the next five years. However, Internet user growth in India is expected to be 3x the world average, growing at a CAGR of ~20%. The type of Internet users in India is set to change dramatically. Less than 10% of India's population lives in Tier 1 cities. Internet penetration in these areas has already reached saturation, and an estimate of 75-80% new user growth will come from rural areas in the next five years. Internet businesses will have newer set of customers who will access content via mobile phones, content in local (Indic) languages and prefer to consume content via videos, rather than text. This gives a huge opportunity for companies developing local language apps and sites, search interfaces, video streaming and broadcasting, download managers, among many others.

The real position of the smallholder farmer

The smallholder farmer, who is much more exposed to the risks of agriculture, includes climate change. The smallholder farmer, who barely has a profit margin, and is often cultivating just to feed his family, so it is he who needs low cost strategies more than anyone else. The recent advancements in Internet and Cell Phone Technology (ICT) bring forth great opportunities to ride over or, 'leapfrog' over the costly and redundant technologies that the smallholder farmer could not have afforded. He can now make use of existing tools and services. Although the decentralized structure of the 500 million smallholder farmers and cooperatives is a challenge, one thing that ICT can and has achieved is connectivity and information flows. Yet, the power and resource to be the first to leverage these technologies has always wrested with the big private companies. It is these private companies who can afford to and should invest in mobile technologies.

How to double the income of India's smallholder farmers

In an effort to boost the agriculture sector, the Indian government has set an ambitious goal to double farmers' income by 2022. In doing so, it has unveiled strategies ranging from irrigation to crop insurance. But if the food value chain is to undergo true transformation, it needs to move from a production-driven system to one driven by demand, one that increasingly connects consumers with producers. This will require new approaches and innovations, as well as increasing collaboration between the private sector and other stakeholders in the farming system. It will require integrated value chains that connect farm to fork, competitive markets that provide better prices to farmers, and an enabling environment that supports innovation and action.

The entry of mobile and cloud-based apps

We've come to a time in civilization when raw materials and resources are becoming ever more scarce. When we take into consideration the pollution, increased emissions, soil degradation and water depletion, we know the sustainability challenges that loom in the horizon are real. But into this same scenario, we lately have the entry of 4G mobile networks worldwide. Although agriculture and mobile apps technology may appear disconnected on the face of it, there is already an increasing amount of evidence to suggest that making use of mobile and cloud-based applications not only addresses these sustainability challenges, but also creates financial value for both large agriculture-based companies and smallholder farmers. The introduction of such mobile technology and portable, wireless devices has led to the creation of innovative services and applications that are used within the agricultural chains in both developed and developing countries. The nature of adoption of these technologies in these two markets does show some variation. In developing countries, where a large proportion of the workforce is employed in agriculture, mobile technology is more commonly used to deliver services for producers and traders. The host of applications of mobile technology in agriculture includes market information such as trading facilities, weather information, peer-to-peer learning and financial services such as payments, loans and insurance.

How mobile apps and technologies help farmers to gain more income

Spreading agricultural related information to farmers in the smallholder communities are made easier with the help of cloud computing, integrated IT systems, online education and proliferation of mobile phones. One of the benefits of such connectivity and information flow is that it helps farmers make better land management decisions. For example, it can enable soil condition to be monitored in conjunction with weather information in order to better plan the planting and harvest season. Similarly, Geographical Information Systems can be used to provide pre-emptive information on pests and animal diseases so farmers can respond accordingly to the level of risk. Optimizing the use of fertilizer, seeds and water can also be done by utilizing mobile and cloud computing technologies. This helps farmers save money while reducing consumption.

ICT Initiatives

Indian users comprise about 30% of the total volume of the global feature phone market, making it the second largest in the specified field. In 2015, India had 720 million mobile phone users, out of which 320 million were rural mobile phone users. This estimate also included 50 million Smartphone users with access to Internet. According to 'The Rising Connected Consumer in Rural India', a study by the Boston Consulting Group, this share of rural India will jump to 48% by 2020. Steps taken by the Indian government, Digital India, launched in 2015 by Indian Prime Minister, aims towards the promotion of digital literacy and creation of digital infrastructure for empowering rural communities. Considering that 58% of rural households depend on agriculture as one of their most eminent source of livelihood, the role of Digital Agriculture needs to be considered within Digital India. The use of Information and Communication Technology (ICT) to support the transmission of localized information and services working towards making farming socially, economically and environmentally sustainable. This has also led to the rise and development of mobile apps, which are helping existing government schemes, and other agriculture-based information to reach farmers in rural India. This digital change is acting as a game-changer for Indian agricultural conditions.

Indian Council of Agricultural Research (ICAR) comprising of a network of 102 research institutes, 71 Agricultural Universities and 642 Krishi Vigyan Kendras

(KVKs) is geared to meet the challenge of Indian agriculture under new WTO regime, enhance the competitiveness of Indian farming to make farming a viable, self-sustaining and internationally competitive enterprise. The efforts initiated towards re-orientation of R&D system by ICAR which include development of quality human resource through quality agricultural education, need-based training in India and abroad, harnessing ICT in agriculture development, strengthening social science skills, promoting public-private sector partnership, strengthening policy analysis and vision-oriented market-led intelligence analysis skills, strengthening agri-business development and IPR management. Further, research and development efforts are focused on high value processed products, linking production with processing and marketing with focus on small and marginal farmers and farm workers (www.icar.org.in).

***District Agricultural Contingency Plans*:** The District Agricultural Contingency Plans (DACP) are technical documents aimed to be ready reckoner for line departments and farming community on prevailing farming systems and technological interventions to manage various weather aberrations such as droughts, floods, cyclones, hailstorms, heat and cold waves addressing different sectors of agriculture including horticulture, livestock, poultry, fisheries. The contingency plans are useful for preparedness and real time implementation towards sustainability agriculture production system in the events of weather aberrations and extreme climatic events.

http://www.crida.in:82/contingencyplanning/

Infoequine: It is a user-friendly bilingual mobile App in Hindi and English language for equine owners, Veterinary officers, Animal Health department officials, students, industry professionals and other stakeholders. This App allows users to enhance their knowledge in various aspects of equines with regard to breeds, management, nutrition, diseases, artificial insemination, pregnancy diagnosis etc. Besides the general information about equines, the information about diagnostic services, artificial insemination services, provision of semen for production of best quality of mules, horses and donkey and technologies developed by the Centre is also provided in the app.

Kisan Suvidha: Indian farmer app (Suvidha is a Hindi word which means to facilitate/ enable/ assist/ make capable enough) launched in 2016 to work towards empowerment of farmers and development of villages, the app design is neat and offers a user-friendly interface. It provides agriculture alerts and agriculture advisories in 11 Indian languages in text as well as agriculture audio clip for the convenience of the farmers who are most comfortable in their own language. It has following modules:

WEATHER- This section provides instant access to weather forecast for next 5 days with temp, RH, rainfall possibility, expected wind speed & its direction in the set preferred location. Farmers may add and remove preferred locations for weather forecast. It will help farmers to plan and take corrective action for agricultural & farming related activities. At a time, 2 districts can be selected as preferences for weather data access. Data source-IMD.

MARKET or MANDI- Farmers can get instant access to mandi prices for their produce, market status and prevailing trade prices along with quantities. Farmers can also view price trends for their produce and plan sale of their produce. Farmer can get last 3-updates on transactions in the market on any agricultural commodity at any point of time. Data source- AGMARKNET & NCEDX.

AGRICULTURAL ADVISORIES- This is the crop specific advisory service for various agro-climatic zones. These advisories and alerts are provided based on research by industry experts; our agricultural advisories guide rural farmers to initiate necessary & corrective actions based on prevailing weather conditions.

ASK OUR EXPERTS - This is the USP of the "IFFCO Kisan" Indian Farmer agriculture App. Through this feature, farmers can talk to industry Agriculture experts and get agricultural advice on 1-click. It is very useful for those farmers who have difficulties in writing; e they can just take a photo of the plant or concerned area/ disease and can send it to our experts to study the issue through the app. Our experts will provide personalized agriculture solutions through voice call.

GYAN BHANDAR- An agriculture information library for the farmer to get all important agriculture information related to crops, agriculture cycle, agriculture field preparation, water management, agriculture diseases management and agriculture proactive actions.

HELPLINEs- Farmers can access the exclusive IKSL '534351' agriculture helpline service through the "IFFCO Green SIM card" to get access to IKSL experts and also get OneTouch connectivity to Kisan Call Centre Services "18001801551" number from the IFFCO Kisan app. KCC is the initiative of Ministry of Agriculture, Government of India. It is managed by IFFCO Kisan Sanchar Ltd.

Market place- This feature is the buyer and seller meeting platform, where a buyer or a seller can register his/her buying or selling requirement/s. It will help them to buy or sell faster, with higher profitability.

Setting- This is where a farmer can set their preferences based on their interests and need; on weather, mandi, advisory, Gyan Bhandar, etc. IFFCO Kisan app users can also change the preferred language.

PROFILE- Farmers can update personal data like crop details, land details, animal details apart from personal information.

IFFCO Kisan Agriculture : This app was launched in 2015 and is managed by IFFCO Kisan, a subsidiary of Indian Farmers' Fertilizer Cooperative Ltd. Its aim is to help Indian farmers make informed decisions through customized information related to their needs. The user can access a variety of informative modules including agricultural advisory, weather, market prices, agriculture information library in the form of text, imagery, audio and videos in the selected language at profiling stage. The app also offers helpline numbers to get in touch with Kisan Call Centre Services.

RML Farmer – Krishi Mitr*:* RML Farmer is a one of its kind agricultural app where farmers can keep up with the latest commodity and mandi prices, precise usage of pesticides and fertilizers, farm and farmer related news, weather forecast and advisory. It also provides agricultural advice and news regarding the government's agricultural policies and schemes. Users can choose from over 450 crop varieties, 1300 mandis, and 3500 weather locations across 50,000 villages and 17 states of India. It works with the help of specific tools designed to analyze or provide information on different aspects of farming habits. Eg. CropDoc helps the farmers in identifying problems that affects their crops at the right time and suggests corrective actions; Farm Nutri provides general and personalized nutrient recommendations, which are presented in the form of a schedule of fertilizer dosage.

Pusa Krishi*:* This app was launched in 2016 by the Union Agriculture Minister. It gives information about technologies developed by Indian Agriculture Research Institute (IARI), which will help in increasing returns to farmers. The app also provides farmers with information related to new varieties of crops developed by Indian Council of Agriculture Research (ICAR), resource conserving cultivation practices as well as farm machinery and its implementation will help in increasing returns to farmers.

AgriApp: It provides complete information on Crop Production, Crop Protection and all relevant agriculture allied services. It also enables farmers to access all the information related to "High value, low product" category crops from varieties, soil/ climate, to harvesting and storage procedures. An option to chat with experts, video-based learning, the latest news, online markets for fertilizers, insecticides etc. are also available on this app.

Kheti-badi *:* 'Kheti-Badi' is a social initiative App. It aims to promote and support 'Organic Farming' and provide important information/issues related to farmers in India. Agriculture today is heavily dependent on genetically modified seeds, chemical pesticides and fertilizers; this app helps farmers to switch their chemical farming into organic farming. However, this app is currently only available in four languages (Hindi, English, Marathi and Gujarati).

Krishi Gyan: Works on a similar aspect as Whatsapp communication but is considered to be better as it doesn't require mobile numbers of individuals to stay connected. Apart from providing general information on farming, this application enables Indian farmers to connect with Krishi Gyan experts and ask them questions related to farming, and get answers within the application through notifications. The farmers as well as agriculture enthusiasts can also share their answer with each other.

Crop Insurance: The app helps farmers to calculate insurance premium for notified crops and provides information cut-off dates and company contacts for their crop and location. It can also be used to get details of normal sum insured, extended sum insured, premium details and subsidy information of any notified crop in any notified area. It is further linked to its web portal that caters to all stakeholders including farmers, states, insurance companies and banks.

AgriMarket: Launched along with the Crop Insurance app by the government of India, the app has been developed with an aim to keep farmers abreast of crop prices and discourage them to go for distress sales. Farmers can get information related to prices of crops in markets within 50km of their own device location using the AgriMarket Mobile App.

Conclusions

The overarching benefits of ICT in agriculture are that it reduces transportation, transactional and corruption waste. It can bring about product traceability, disease and pest tracking, and storage. The ICT development has made the rural people better informed about the market and the many Indian farmers are benefitted with the reach of ICT in the form of mobile phone or Internet in the remote villages. Only through strong linkages from diverse stakeholders can create the conditions needed for unlocking the entrepreneurship of smallholder farmers and ultimately boosting their income.

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Pulses for Nutritional Security: Constraints and Opportunities

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Pulses are one of the most important ingredients in the diets of majority of the Indian population especially for vegetarian who fulfill their daily protein requirement by consuming pulses along with cereals. Pulses have long been considered as the poor man's meat being the major source of protein. The supplementation of pulses with cereal based diets is considered as one of the possible solution to reduce protein energy malnutrition. Pulses are rich in protein, while it also contains a wide range of nutrients, including carbohydrate, dietary fibre, unsaturated fat, vitamins and minerals (Table 1), as well as non-nutrients, such as antioxidants and phytoestrogens.

Table 1: Nutritive value of major pulses grown in India

Pulse Crops	Protein (%)	Fat (%)	Carbo hydrates (%)	Minerals (%)	Fibre (%)	Calcium (mg)	Iron (mg)	Energy (Kcal)
Red Gram	22.3	1.7	57.6	3.5	3.5	73	2.7	335
Chickpea	17.1	5.3	60.9	3.0	3.9	202	4.6	360
Green gram	24.0	1.3	56.7	3.5	4.1	124	4.4	334
Black gram	23.9	1.4	59.6	3.2	3.1	154	3.8	347
Lentil	25.1	0.7	59.0	2.1	0.7	69	7.0	343
Peas	19.7	1.1	56.5	2.2	4.5	64	4.8	315
Month bean	23.6	1.1	56.4	3.5	4.5	150	10.8	330
Field bean	24.9	0.8	60.1	3.2	1.4	103	6.7	347
Cowpea	24.0	1.0	54.5	3.2	3.8	110	8.27	323

Source: NIN, Hyderabad, ICMR

The high concentration of dietary fibre, required essentially for healthy bowel function and soluble fibre helps in lowering blood cholesterol. Pulses also have low glycemic index or GI (<55), which is very useful for reducing glucose and insulin levels in blood stream, thus reduces the risk factors for cardiovascular diseases and type 2 diabetes. The antioxidants, vitamin E, selenium, phenolic acids, phytic acids, copper, zinc, manganese and folate in pulses helps in the prevention of heart disease and cancer. Unlike wheat, pulses are also gluten-free and very good for people on gluten-free diet (e.g. people suffering from celiac disease, a gastro-intestinal disorder). Although, all pulses are rich in various nutrients, there is a high variation in different nutrients contents among different pulse crops (Fig. 1). Every part of the pulse crops are being used for one or the other purposes and it has the ability of biological nitrogen fixation, carbon sequestration, soil amelioration. Being a low water requiring crop, it is an integral component of sustainable crop production system since time immemorial, especially in the dry areas (Ali and Gupta, 2012). It also offers

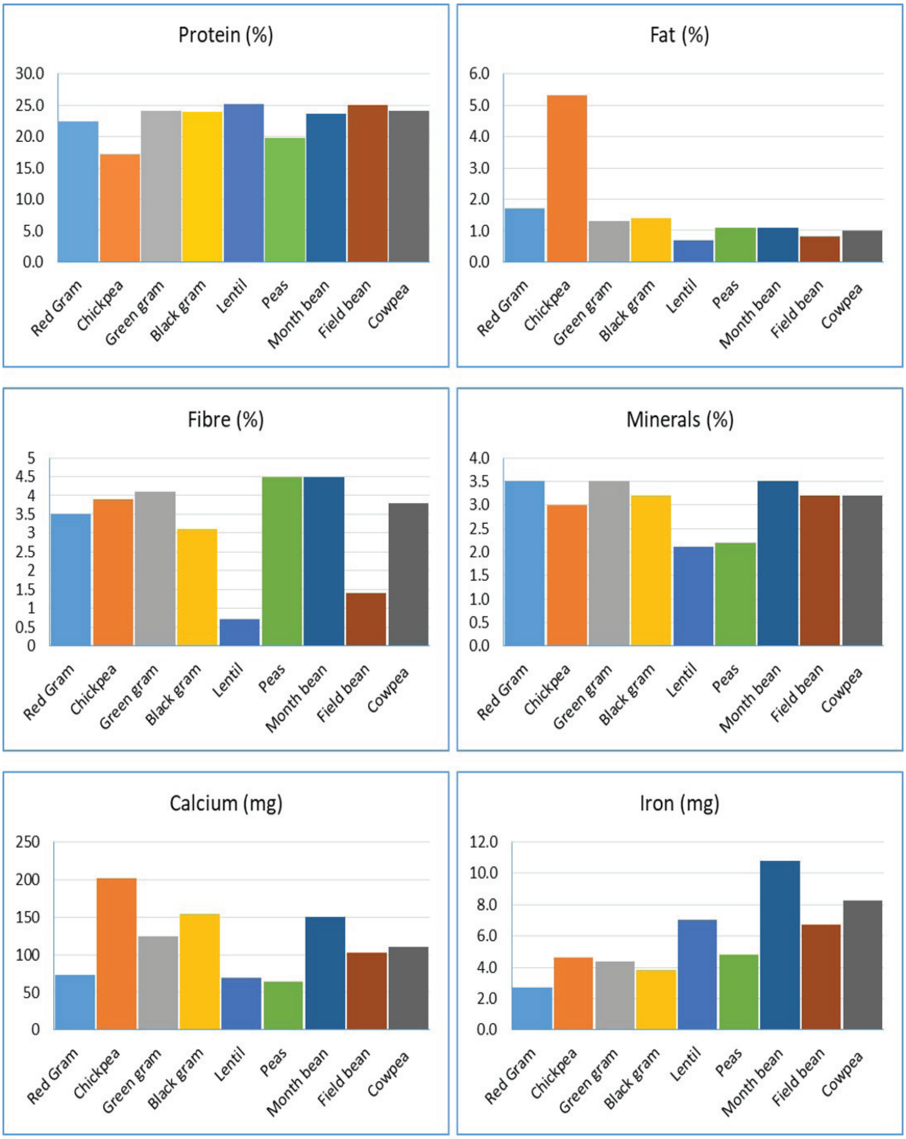

Fig. 1: Comparative nutritive values of different pulses grown in India

good option for crop diversification and crop intensification. Pulses are also an excellent feed and fodder for livestock. Pulses are among the lowest water consuming crops. The rainfall needed for pulses are 15-20% to that of sugarcane and banana, 30-35% that of rice (Fig. 2). Four thousand litres of water are required to grow one kg of rice while, pulses can be cultivated without irrigation with residual moisture only. Pulses can serve as one of the best alternative to high water consuming crops as water table is depleting across the country under this era of climate change and also in ensuring nutritional security of the country.

Production Trends

Pulses production in India fluctuated between 13 and 15 million tonnes with no significant growth trend between 1991 and 2010 while during last five years 2011 to 2015, pulses showed a significant improvement in production (Fig. 3). The record production of 19.25 million tonnes was recorded during 2013-14 with average productivity of 764 kg/ha. This was mainly attributed due to increased area under pulses, as the yield level is still low to the global average of 1562 kg/ha (FAOSTAT, 2016). As a result, per capita availability of pulses is low in India. The major challenges remain to produce more to feed the ever increasing population. It is estimated that with the present Indian population growth rate of 1.44% and assuming a moderate requirement of 50 g pulses per capita per day and with 10% additional need for seeds, feed, wastage, etc., the projected pulses requirement for the year 2030 will be 32 million tonnes which require an annual growth rate of 4.2% in production (IIPR Vision 2030), while projected demand of nearly 50 million tonnes over the mid of this century (IIPR Vision 2050). With the recent surge in the prices and commitment of the policy makers and researchers to make the country self-sufficient on pulses, the main focus is to bridge the yield gaps between realized and potential yield by using available technologies including improved varieties at farmers yield, and also by expanding more area under the improved varieties / technologies. The incorporation of pulses in cropping system will also be very useful in ameliorating the adverse impact on natural resources due to continuous cultivation

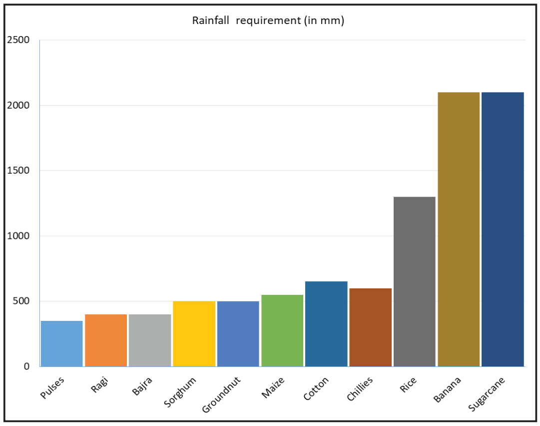

Fig 2: Comparative rainfall requirement of various crops

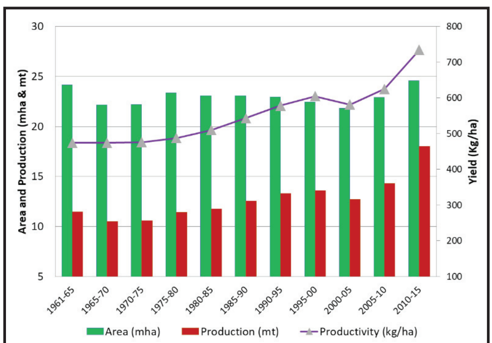

Fig. 3: Area Production and productivity of pulses over last five decades

of high input intensive cereal crops like the rice-wheat cropping system in Indo-Gangetic belt in the country.

The area, production and productivity trends of different pulse crops, like pigeon pea, chickpea, black gram and green gram (Fig. 4) had shown fluctuation between years. Productivity fluctuated more over the years in pigeon pea while there was steady improvement in chickpea productivity. The major states for pigeon pea are Maharashtra (32%) followed by Karnataka (13.5%), MP (12%), Uttar Pradesh (10.7%), Gujarat and AP while, highest productivity was reported from Bihar (mainly being long duration varieties)

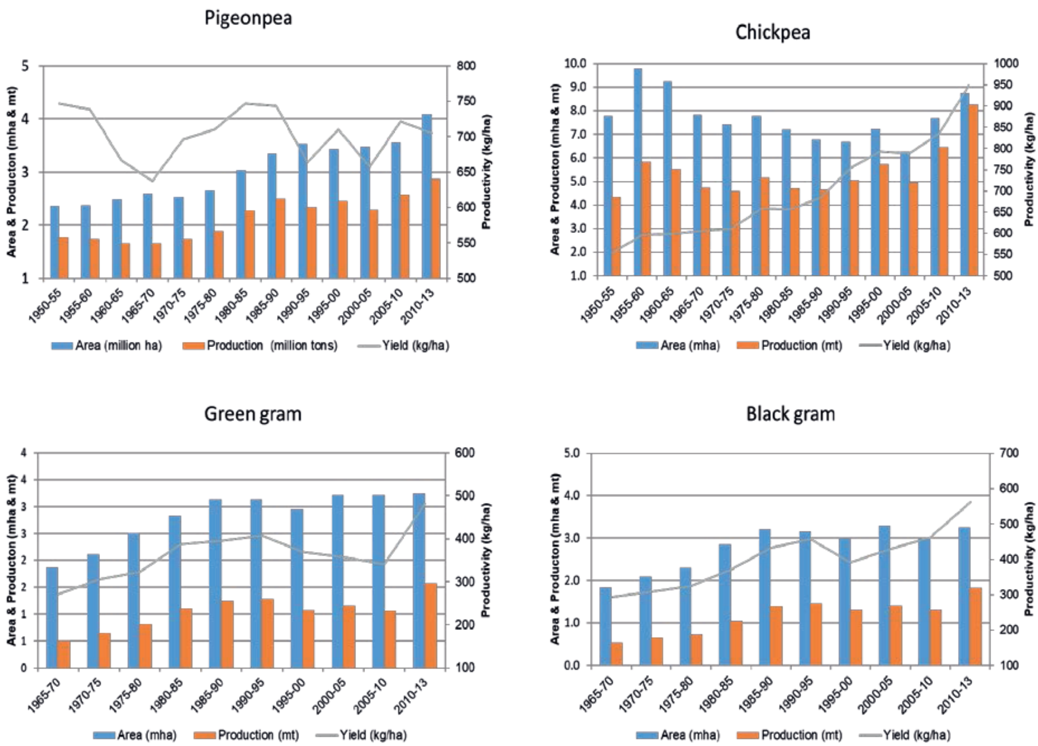

Fig. 4: Area Production and productivity of major pulses over last five decades

followed by Haryana, UP, Punjab, Gujarat, Orissa and Maharashtra. The major green gram producing states are Rajasthan (38.4%), Maharashtra (14%), AP (9.9%), Bihar (6.4%), Tamil nadu (5.8%) and Karnataka (4.3%). In case of black gram the major states are UP (20.8%), AP (20.7%), Maharashtra (12.5%), MP (8.3%) and Rajasthan (7.2%). The major chickpea areas are in MP (43%), Rajasthan (13%), Maharashtra (11%), UP (9.5%). Lentils are also cultivated in more than a million hectare area in India where major production comes from UP (43.6%), Bihar (22%), MP (19%) and West Bengal (5.3%). Out of overall 23.55 mha area under pulses in India during year 2015-16, around 18 mha was mainly contributed by the states of Madhya Pradesh, Rajasthan, Maharashtra, Karnataka, Uttar Pradesh and Andhra Pradesh with a production of 12.57 million tonnes (73.2%). The highest productivity recorded was 1004 kg / ha in Jharkhand, followed by Gujarat (972 kg/ha), West Bengal (941 kg/ha), Andhra Pradesh (911 kg/ha), Madhya Pradesh (876 kg/ha).

Globally, pulses are the second most important group of crops after cereals. During the year 2015-16, the global pulses production was 81.80 million tonnes from an area of 82.38 million hectares with an average yield of 1562 kg/ha (FAOSTAT, 2016). Dry beans contributed 32.8% to global pulses production followed by dry peas (17.56%), chickpea (14.77%), lentils (7.72%) and pigeon pea (5.49%). Mung bean (green gram) and urdbean (black gram) is mainly the crop of India and are grown to a limited extent in south Asian countries including Myanmar, Bangladesh, Sri Lanka and Pakistan. Developing countries contribute about 74% to the global production. India, China, Brazil, Canada, Myanmar and Australia are the major pulses producing countries in the world. Major producers of pulses for the year 2015-16 are given in Fig. 5. India accounts for 33% of the world area and 21.4% of the world production of pulses. The major pulse crops grown in India are chickpea, pigeon pea, lentil, moong bean, urdbean and field pea. Apart from these, arid legumes cowpea, horse gram, moth bean and cluster bean are also grown to a limited extent mainly in dry areas of country. These crops are cultivated under a wide range of agro-climatic conditions. Majority of the pulses comes from rainfed, resource poor and harsh environments, frequently prone to drought and other abiotic stress condition.

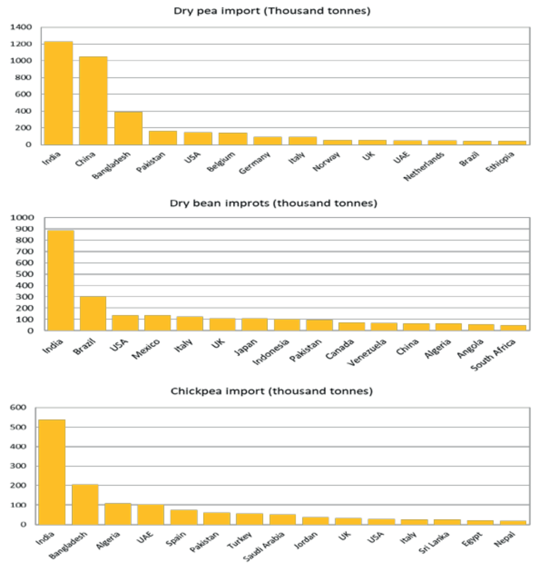

Fig. 5: Major pulses producers in the world

India's Trade of Pulses: India is not only the largest producers and consumers of pulses, but also one of the largest importers of pulses in the world, as the demand for pulses is much higher than their domestic production. The increasing demand of pulses could not keep the pace with the ever-increasing population and consequently, per capita availability has progressively declined from 60 g in 1950-51 to 32 g at present. To meet the domestic demand, the country imported about 4.58 million tonnes pulses costing more than Rs.

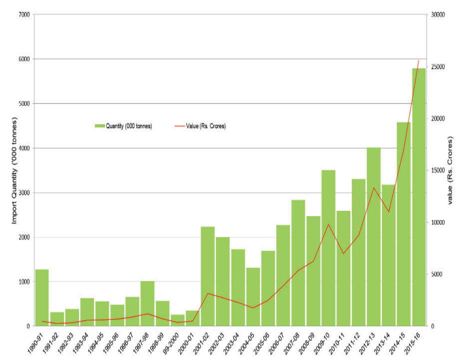

Fig. 6: India's Import of total pulses over the years

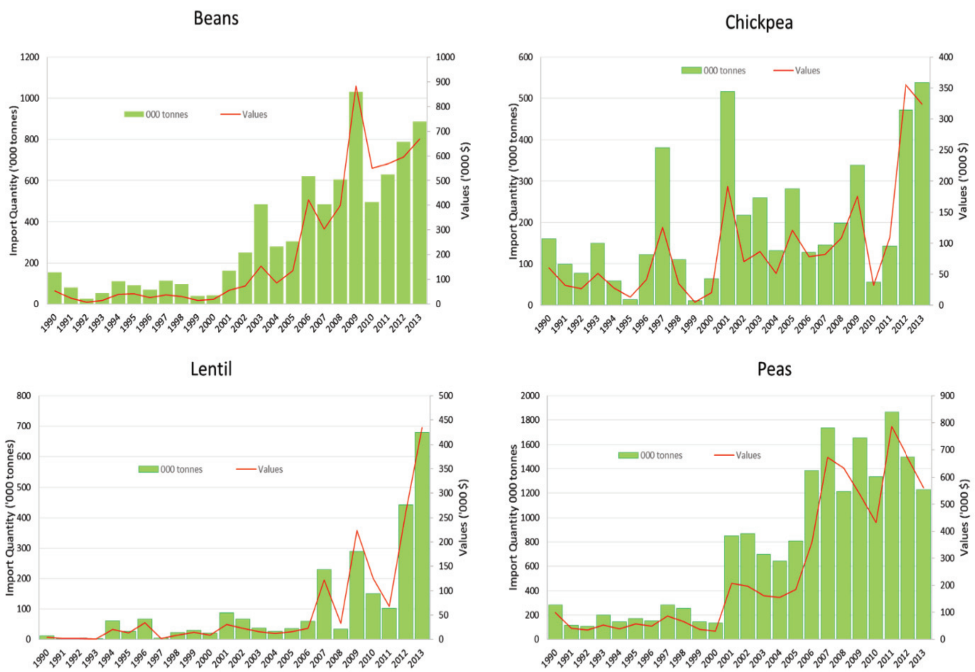

Fig. 7: India's Import of different pulses over the years

17062 crores (2014-15) in government exchequer (Source: Agricultural Statistics, DAC, Ministry of Agriculture, 2016). There has been consistent increase in import burden of pulses over the year since 1990's (Fig. 6). Among the pulses, chickpea, dry beans and dry peas (Fig. 7) are mainly being imported by India and it also happen to be the largest importer among importing countries during 2015-16 (FAO Statistics, 2016). The pulses shortfall may increase to 6.8 mt by 2020-21 with an anticipated increase in per capita consumption of pulses from 9 kg per year in 2007-08 to 10.9 kg by 2020-21 (Joshi, 2009). India also export some quantity of pulses to different countries. India's top destination for export and import of pulses are given in table 2.

Table 2. India's Trade destinations of Major Pulses for 2015-16

Pulses	Top Export Destinatio ns	Top Import Sources
Peas	Shri Lanka (81.07%), Nepal (12.56%), Ukraine (4.28%), USA (1.63%), Bangladesh (0.42%)	Canada (60.97%), Russia (14.82%), USA (6.96%), France (5.36%), Luthuania (4.15%)
Chickpeas	Pakistan (35.60%), Algeria (15.17%), Turkey (8.58%), Sri Lanka (8.07%), UAE (4.97%)	Australia (74.40%), Russia (16.49%), Tanzania (2.79%), Myanmar (0.92%), USA (0.74%)
Moong/ Urad	USA (39.96%), Sri Lanka (13.05%), UK (9.86%), Australia (7.77%), Malaysia (7.63%)	Myanmar (70.37%), Kenya (7.43%), Australia (6.32%), Tanzania (3.15%), Uzbekistan (2.60%)

Pulses	Top Export Destinatio ns	Top Import Sources
Lentils (Masur)	Sri Lanka (43.39%), Bangladesh (18.11%), UAE (8.35%), Egypt (3.98%), USA (3.67%)	Canada (89.58%), USA (7.47%), Australia (2.88%), Turkey (0.03%), Mozambique (0.03%)
Pigeon peas (Tur)	USA (40.79%), UAE (18.28%), Canada (11.28%), UK (10.75%), Singapore (5.11%),	Myanmar (46.35%), Tanzania (18.71%), Mozambique (15.36%), Malawi (12.56%), Sudan (3.36%

Source: Department of Commerce, Govt. of India

Shift in pulses cultivation in India

With the increasing irrigation facilities, the Indo-Gangetic plains (IGP) of northern India, which used to be the pulses basket of the country is showing a declining trend in area, mainly replaced by wheat, rice and maize. There has been a major shift in chickpeas area (about 3.0 million hectares) from northern India (cooler, long season environment) to southern India (warmer, short season environment) over last few decades (IIPR Vision 2030). The short-duration varieties developed by International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) along with National Agricultural Research System (NARS) have played a key role in expanding area and productivity of chickpea in central and southern India. In the north, the predominant rice-wheat cropping system has been left with little scope for expansion of pulse crops, while in south India, there are vast patches of rice fallows, which can be utilized for chickpea, as there is no strong competitive crop in the post rainy/winter season. The area under pulses declined from 10.12 million hectares to 8.16million hectares (about 20%) in north India while, increased from 11.34 to 15.01 in central and south India during the last four decades (IIPR Vision 2030). Among pulses, chickpea area decreased more than 50% from north India during 2006-10 considering the base year 1971-75 (Fig. 8). On the contrary, Andhra Pradesh set an example for remarkable increase in the area, production and productivity in chickpea. Among the major pulses producing states, Andhra Pradesh leads in the productivity of chickpea and pigeon pea. The area, production and yield of lentil has also increased significantly in Madhya Pradesh. Andhra Pradesh while,

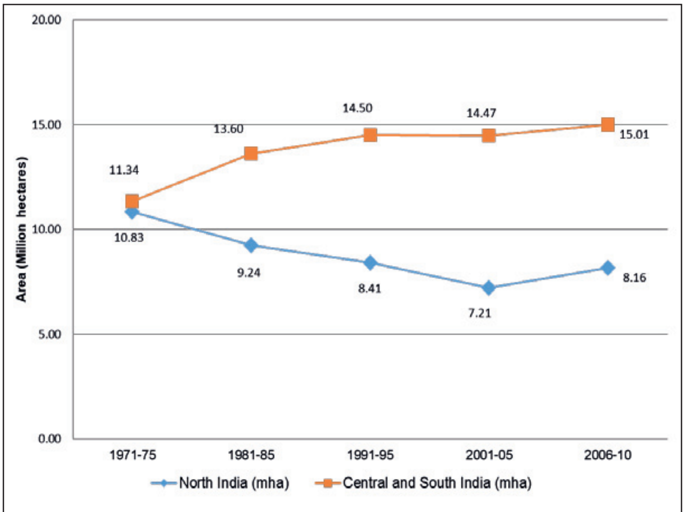

Fig. 8: Geographical shift in pulses area in India (Source: IIPR Vision 2030)

Karnataka showed an increasing trend in production of pigeon pea. Contrary to this, area of mung bean and urdbean has increased to almost double in north along with significant increase in the productivity of this two important summer crops. The major reasons for increasing both area and productivity in these two summer / rainy season crops could be, due to incorporation of many short duration varieties with synchronous maturity as catch crops in various cropping systems under irrigated condition.

Abiotic and biotic stresses in pulses production

Despite best efforts, pulses production and productivity has been stagnant over last several decades. Pulses are mainly cultivated on marginal lands as it does not attract much of the farmer's attention. These crops are also adversely affected by number of biotic and abiotic stresses, which are responsible to a large extent of the instability and low yields.

Abiotic stresses

As pulses are grown on marginal lands under rainfed conditions with low inputs, it suffers heavily due to various abiotic stresses, resulting into low productivity. There has been a high degree of risk in pulses production due to various abiotic factors as more than 87% of area is under rainfed conditions. The predicted changes in temperature and their associated impacts on rainfall and consequent availability of water to crops and extreme weather events are all likely to affect substantially the potential of pulse production (Ali et al, 2009) especially in the era of climate change. Climate change has emerged as a major challenge to agriculture. The high intra-seasonal variability of rainfall, extreme events and unseasonal rains causes heavy losses to our crops every year. Although average rainfall of major pulse growing states such as Madhya Pradesh (MP), Uttar Pradesh (UP), Gujarat and Maharashtra is about 1,000 mm, the moisture stress at different stages of crop cycle is one of the main reasons for crop failures. Terminal drought and heat stress also leads to forced maturity with low yields. Drought stress alone may reduce seed yields by 50%. Crops like pigeon pea is very sensitive to fluctuations of temperature, either lower or higher extremes leading to massive flower drop resulting an adverse impact on pod setting. Cold stress also affect the grain yield, where pigeon pea is sensitive to low temperatures and chickpea to chilling temperatures especially in areas of north India. Salinity and alkalinity is high both in semi-arid tropics and in the Indo-Gangetic plains in irrigated areas, which is another cause for concern, as most pulses are susceptible to salinity and alkalinity.

Biotic stresses

Pulses are affected by large number of insect-pests resulting in heavy losses in cases of severe infestation. Among various insects pod borer (*Helicovera armigera*) causes maximum damages, followed by pod fly. Another important pest affecting pulses are nematodes, among which root-knot nematodes causes substantial yield losses. Among diseases, wilt in chickpea, sterility mosaic virus (SMD) in pigeon pea, yellow mosaic virus (YMV) and powdery mildew (PM) are common in mung and urdbean causing major damages. A few varieties possessing resistance to one or two diseases such as wilt resistance in chickpea (ICP-8863) released by ICRISAT have had the highest impact in terms of adoption. Its adoption in northern part of Karnataka state, has increased its area from 5% in 1987 to almost 80%. It has resulted in stabilization of production, expansion of crop area and increased income. The chickpea varieties JD-315, KWR-108, ICCV-10 and H-82-2 also had limited success. SMD resistance in pigeon pea varieties (Bahar and Pusa-9), YMV resistance in moong bean (PDM139, Pant Moong-4, Samrat, IPM2-3, IPM2-14) and urdbean (Pant-U-19, Uttara, Narendra, Uttara and IPU2-43), PM resistance in pea (HFP-4, Shika, IM-9102 and DMR-11) and rust resistance in lentil (DPL-62, DPL-84 and Pant-L-406) varieties have also been developed to control biotic stresses.

Issues in relation to pulses cultivation

To meet the increasing demand of pulses, we not only need to produce more but also have to be competitive to protect the indigenous production and reduce dependence on import. There is a need to develop and adopt productive and efficient technologies along with supportive policies to encourage farmers to cultivate pulses. Renewed emphasis need to be given to bridge the gap between yield potential of improved varieties in experimental / on-farm trials and actual yield realized at farmers field through efficient dissemination of improved technologies. Farmers usually apply minimal or no fertilizers, insecticides and limited irrigations for growing pulses. As a result wide gaps exist between yields realized in experimental plots, frontline demonstration plots and at farmers' fields. Improved varieties of different pulse crops hold promise to increase productivity by 20–25%, whereas appropriate package of practices comprising improved varieties and integrated management of nutrients and pests has shown 25–42% yield advantage over the farmers' practices in a large number of frontline demonstrations conducted across the country (Ali and Gupta, 2012). Improved production technologies like raised bed planting, ridge furrow planting, seed treatment with Rhizobium, application of sulphur @ 20 kg/ha, pre-emergence application of pendimethalin @ 1–1.25 kg/ha, foliar spray of 2% urea/DAP, and bio-intensive IPM modules have been advocated after experimentation and large-scale frontline demonstrations.

The major issues which need to be addressed to bridge yield gap in pulse production and making India not only food secure but also nutrition secure are:

- ***Poor realized yield***

  Yield realization in pulses is very low due to shifting of pulses cultivation from high productivity zone to low productivity zone, largely in rainfed areas and with poor crop management. The weather has also become highly unpredictable with temperature extremities and variable rainfall pattern in the era of climate change. There is an urgent need to develop improved varieties along with appropriate production technologies to address the issue of low productivity.

- ***Improving yield stability***

  Most of the pulse crops are still going through evolutionary process which also has very narrow genetic base, inefficient plant type, and indeterminate types, less responsive to inputs, poor source-sink relation resulting poor yield potential of these crops. As a result yield stability under rainfed situation always remains a major challenge in pulses cultivation. This issue can be addressed to some extent by efficient water management in rainfed area through rainwater harvesting and recycling through farm ponds, advocating short duration varieties in drought prone areas to escape drought. Promoting micro irrigation system, adoption of moisture conservation practices can be handy in maximizing yield under rainfed condition.

- ***Availability of quality seed and poor seed replacement***

  The availability of quality seeds of improved varieties is very less and there is also lesser participation of private seed sector in seed production resulting poor seed replacement rate in pulses. With the active involvement of public sector seed corporation, government agencies, private sector, and farmers help groups in production of quality seeds, the requirement of quality seeds to the farmers can be ensured. Recently, under National Food Security Mission (NFSM), government has initiated a massive seed production project on pulses involving >150 KVKs and various institutes under ICAR and State Agriculture Universities, which is expected to fulfil the requirement of quality seeds of pulses to the farming community in the country.

- ***Post-harvest losses***

  There has been a substantial amount of post-harvest losses in pulses due to lack of efficient harvester and thresher at affordable price to farmers, use of traditional dal mills with low dal recovery and lack of proper storage facility resulting in high infestation with stored grain pests (bruchids). This compels the growers to dispose of their produce immediately after harvest at low price. Post-harvest losses can be reduced by development and popularization of improved harvesters, threshers and graders in private-public partnership, modernization of existing dal mills.

- ***Wide fluctuation in prices***

  Unlike wheat and rice where government procurement system is very effective with MSP support, the procurement and selling of pulses is highly unorganized and prices are subjected to market fluctuation. Of late government has initiated effort with higher MSP for pulses which will encourage the farmers to go for pulses cultivation.

- ***Timely availability of critical inputs***

  The timely availability of quality seeds, bio-fertilizers, bio-pesticides (NPV, Trichoderma) and micro-nutrients at the time of sowing is an important issue which needs more attention for improving the production and productivity in pulses. Timely and advanced forecasting system of prevailing diseases and their control measure, promotion of IPM technologies for pest like pod borers will be useful in ensuring higher productivity of pulses.

- ***Efficient dissemination of improved technologies***

  An efficient system for disseminations of improved technologies from researcher field to farmer's field is essential. However lack of trained extension personnel, resulting lack of exposure of farmers to improved technologies is another important issues which needs to be addressed. Poor interface among state departments of agriculture, research organization and private agencies are major reason for poor productivity. Organization of farmers days for demonstration trials, farmers training and exposure visit, popularization of improved technology through mass media, better linkage between research organizations, state departments of agriculture and private agencies will be useful in increasing area, production and productivity of pulses in the country.

Strategies for ensuring nutritional security

The major strategies for making the country self-sufficient in pulses production for ensuring nutritional security, are to bring additional area under pulses by identifying new niches of pulses and improving productivity by developing improved varieties and production technologies.

Bringing additional area under pulse crops

The continuous rice-wheat production system in Indo-Gangetic plains is mainly responsible for deterioration of soil health and depletion of water level which needed diversification of sustainability of production system. Diversification of rice-wheat system in IGP through popularization of short duration pigeon pea, kabuli chickpea, field pea and summer mung bean will not only enhance pulses production to make country nutritionally secure but also improve soil health by adding nitrogen and make agriculture more sustainable. The utilization of vast area under rice fallow through urdbean / mung bean in coastal peninsular region and lentil in eastern plains will bring additional area under pulses which will add to the increase in national production. Also promotion of short duration thermo-insensitive varieties of mung bean or urdbean in spring/summer will further help in increasing production.

Improvement in pulses for different agro-ecologies

The effort should continue with renewed emphasis, using both conventional and molecular breeding approaches for developing high yielding varieties for different agro-ecologies. To incorporate resistance to biotic and abiotic stresses, effort should be made by exploiting and utilizing unexplored gene pool and wild relatives for transfer of genes of interest into cultivated background. Emphasis should be given in developing of high yielding short duration varieties having multiple resistance to insect-pest and diseases. Development of efficient plant type responsive to high input and exploitation of hybrid vigour in crops like pigeon pea will further help in increasing the production and productivity. Under the All India Coordinated Pulses Improvement programme of Indian Council of Agricultural Research (ICAR) at Indian Institute of Pulses Research (IIPR), Kanpur, effort are made to improve production and protection technologies for enhancing production and productivity of pulses in the country. With these concerted effort of various ICAR institutes including the Indian Institute of Pulses Research, state agricultural universities and international centres like ICRISAT and ICARDA, number of high yielding improved varieties (table 3-7) was developed for different pulse crops coupled with appropriate production and protection technologies for improving the production of pulses in India.

Table 3. State wise promising varieties of chickpea

State	Varieties
Andhra Pradesh	JG 11, KAK 2, JAKI 9218, MNK-1, ICCV 37
Bihar	Gujarat Gram 4, Pant G 186, HK 05-169, Pusa 372
Gujarat	JG 16. Gujarat Gram 1, Gujarat Junagadh Gram 3, JSC 56
Karnataka	ICCV 37, JAKI 9218, JG 11, MNK-1, Phule G 0517
Madhya Pradesh	JG 322, JG 16, JG 14, JAKI 9218, JG 315, JSC 56, PKV Kabuli 4
Maharashtra	JAKI 9218, KAK 2, Phule G 0517, JSC 55, JSC 56, PKV Kabuli 4
Rajasthan	Pratap Chana-1, GNG 1499, RSG 973, RSG 963, CSJD 884
Uttar Pradesh	KPG 59, KGD 1168, KWR 108, HK 05-169, Pusa 372

Table 4. Recommended varieties of mung bean for different states and seasons

State	Season	Varieties
Andhra Pradesh	Rainy Spring	IPM 02-14, COGG 912, Warangal-2, LGG 407, Madhira 295, Pusa 9072, LGG 460, TM 96-2, WGG-2
Bihar & Jharkhand	Rainy Spring / Summer	Pant Moong 4, PDM139, HUM-1, IPM 2-3 PDM 139, Pant moong 5, HUM-16, HUM 12
Madhya Pradesh	Rainy Spring/Summer	JM 721, Jawahar 45, HUM-1, Meha, TJM 3 HUM 1, Pusa 9531, PDM 139, Meha
Maharashtra	Rainy	Phule M 2, TARM 1, TARM 18, TARM 2, BM 200-1, HUM 1
Orissa	Rainy Spring	TARM 1, PDM 139 TARM-1, OBGG-52, LGG-460, PDM 139
Rajasthan	Rainy Spring/Summer	RMG 268, MUM 2, SML 668, IPM 2-3 RMG 268, SML 668, PDM-139, Meha, IPM2-14

State	Season	Varieties
Uttar Pradesh	Rainy Spring/Summer	Narendra Moong 1, Pant Moong 4, Pant Moong 5. PDM 139, Pant moong 5, TMB 37, HUM-16, HUM 12
West Bengal	Rainy Spring/Summer	Pant Moong 5, MH 2-15 Meha, Pant moong 5, TMB 37, HUM-16

Table 5. Recommended varieties of urdbean for different states and seasons

State	Season	Varieties
Andhra Pradesh	Rainy	LBG 648, Pant U 31, LBG 752, LBG 623, LBG-709
Karnataka	Rainy	KU 301, WBG 26, WBU 108, LBG 402
Madhya Pradesh	Rainy	JawaharUrd 2, Jawahar Urd 3, Khargone 3, Pant U 30
Odisha	Rainy Spring	KU 301, WBG 26, WBU 108, IPU 2-43 TU 94-2, OBG 17, Mash 338
Rajasthan	Rainy Spring	IPU 94-1 (Uttara), Pant U 31, KU 300 KU 300, KUG 479
Uttar Pradesh	Rainy Spring	IPU 94-1 (Uttara), Narendra Urd 1, Pant U 40 KU 92-2, KU 300 (Shekhar 2), Narendra Urd 1
Tamil Nadu	Rainy Rice-fallow	ADT 5, Vamban 2, Vamban-4, IPU 2-43, VBG 04-008 Vamban-3, TU 94-2, VBN-5, KBU 512, Vamban 2

Table 6. Recommended varieties of Pigeon pea for different states

State	Variety/Hybrid
Maharashtra	BDN 2, ICPL 87, Asha, BSMR 736, BDN 708.
Madhya Pradesh	Asha, JKM 7, MA 3, JKM 189
Gujarat	BDN 2, ICPL 87, GT 100, Asha, GT 101,
Andhra Pradesh	Maruthi, ICPL 87, Asha, LRG 30, Lam 41, PRG158, PRG176
Karnataka	Asha, BRG 1, BRG 2, Hy3C, TS 3R,WRP 1
Tamil Nadu	ICPL 87, Co 5, Vamban 1, Asha, CORG 9701, Vamban 2
Uttar Pradesh	UPAS 120, NDA 1, NDA 2, Azad, MAL 13, NDA 3
Bihar	NDA 1, UPAS 120, Birsa Arhar 1
Rajasthan	UPAS 120, Pusa 855

Table 7. State wise promising varieties of Lentil

States	Varieties
Uttar Pradesh	DPL 62, Narendra Masoor 1, IPL 406
Bihar	HUL 57, WBL 77, Arun
Madhya Pradesh	IPL 81, JL 3, IPL 406
West Bengal	HUL 57, WBL 77 KLS 218, Ranjan (B 256), Asha (B 77),
Assam	HUL 57, WBL 77, KLS 218, B 77
Orissa	HUL 57, WBL 77, B 77

Conclusion

Pulses are important natural foods for meeting the daily requirements of proteins. Presently about 25 million hectares of land is under pulses cultivation in India producing about 16.5 million tonnes of pulses. We still need to import 3-4 million tonnes of pulses annually to meet the domestic demand, despite being the largest producer of pulses in the world. It is a challenge to ensure supply of sufficient quantity of pulses in the era of climate change where pulses are subject to various abiotic and biotic stresses. The limited genetic potential for high yields and susceptibility of pulses to pests and diseases make it even more difficult to break yield stagnation in pulses in rainfed conditions. Intensive effort are needed to breed for new improved varieties that fits well into different cropping systems. Research efforts employing cutting edge science tools like genetic engineering will assist in developing transgenic against major pests like pod borer to enhance to productivity of pulses.

Besides varietal improvement, emphasis are needed for development appropriate crop production and protection technologies to make it profitable for farmers to cultivate pulses. Use of drip irrigation in case of pigeon pea and agronomic practices like transplantation and nipping of branches are showing encouraging results. With better yields, development of pest resistant varieties and increased MSP support, farmer will adopt pulse based cropping systems to produce more pulses with increased acreages. Given the important role that pulses play in the human diet, there is also a possibility of increasing production and productivity using available varieties through adoption of appropriate package of practices. The intervention of different stake holders and supply of inputs at proper time along with policy support will help in breaking yield gaps and increasing national production of pulses to ensure nutritional security for the country.

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Delineation of Adopted Village in to Micro Watershed for Enhancing Resources Use Efficiency at Cadastral Level

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The rising demand for water along with further increase in population and economic growth can result in a more intensive use of natural resources, and increasing pressure on biological systems and on production systems in rainfed agriculture. Available water resources were exacerbating the situation. Hence, it is essential to manage and conserve water resources (surface water and groundwater) in a watershed mode to meet the supply and demand. The objective of watershed management is to restore the ecological balance by harnessing, conserving and developing natural resources (soil and water). Watershed management prevents soil erosion, reduces the runoff, increases fodder production and enables the cropping system which helps sustainable livelihoods of the people in residing in the watershed (Dhruvanarayana et.al 1987). An assessment of management options with improved technologies and planning methods would be a key strategy to minimize the risk for dry spell induced crop failures with integrated water resource management(Rockström et al., 2010)in terms of water related constraints to food production, high prevalence of malnourishment and poverty, and rapidly increasing food demands. We argue that major water investments in agriculture are required. In these regions yield gaps are large, not due to lack of water per se, but rather due to inefficient management of water, soils, and crops. An assessment of management options indicates that knowledge exists regarding technologies, management systems, and planning methods. A key strategy is to minimise risk for dry spell induced crop failures, which requires an emphasis on water harvesting systems for supplemental irrigation. Large-scale adoption of water harvesting systems will require a paradigm shift in Integrated Water Resource Management (IWRM. Watershed based management has potential approach for sustainable agriculture, which covers diverse activities of soil and water conservation, rainfed agriculture, afforestation, wasteland development and rural employment (Singh. A 2000). In-situ moisture conservation and rainwater harvesting and recycling are the key resilient rainfed technologies for drought mitigation and sustainable food security (Srinivasa Rao et al., 2014). Evaluation of 37 watersheds located in different agro-eco regions in India indicated significant increase in physical, biological and socio-economic parameters and recommended water harvesting structures and establishment of vegetation for success of the programme (Reddy et al., 2004). The micro-watershed is the basic unit for planning and interventions. Hence delineation of adopted villages into micro watersheds enhances the resources (soil and water) use efficiency at cadastral level.

Delineations of watershed

Topographically delineated area into a geo-hydrological unit draining at a common point is called watershed. There are two methods of delineation of watershed, a) Manual delineation using topographic map sheets b). Automatic delineation of drainage and watersheds by using digital elevation model (DEM) data using computational methods (GIS).

Manual delineation of watershed

Topographic maps created by Geological Survey of India can be used to determine the watershed's boundaries.

1. Draw a circle at the outlet or downstream point.
2. Put small "X's" at the high points along both sides of the watercourse, for headwaters of the watershed.
3. Starting at the circle that was made in step one, draw a line connecting the "X's" along one side of the watercourse. This line should always cross the contours at right angles.
4. Continue the line until it passes around the head of the watershed and down the opposite side of the watercourse. Eventually it will connect with the circle from which it started.

   Final boundary indicates delineated the watershed is show in in Fig.1. (www.nrcs.usda.gov.)

Automatic delineation

Automatic delineation is derived from digital elevation model (DEM) using using computational method in GIS. This procedure is implemented on a PC. Contour maps are converted into digital contour files and spatial interpolation of elevation values from irregularly spaced points to regular grid points as result elevations are at a matrix of points equally spaced in horizontal and vertical direction is called DEM (Clarke et.al., 1982). GIS is used to create watershed delineations using a combination of DEM, digitized network, and other user inputs.

Steps involved in watershed delineation::

1. DEM setup,
2. Stream Definition,
3. Outlet and Inlet Definition,
4. Watershed Outlet(s) Selection and Definition

The threshold area method can be used to delineate the watershed and stream network. The threshold area defines the drainage area required to form the beginning of a stream. Sub basin parameters and basic watershed characteristics can be calculated from the DEM and sub-watershed themes. The results of the calculations are stored as additional fields in the streams and sub basins theme database files. Final figure displays shows the delineated watershed with sub basins (Fig.1).

Case study: An adopted village, Kalchatla, district Kurnool, Andhra Pradesh, is delineated to a Kalchatla micro watershed for different technological interventions. The delineated microwatershed area of 1741 ha which includes the cadastral boundary of the village. Technological interventions to be implemented in a sub-micro watershed of 142 ha and which can be integrated to total micro watershed (Fig.2).

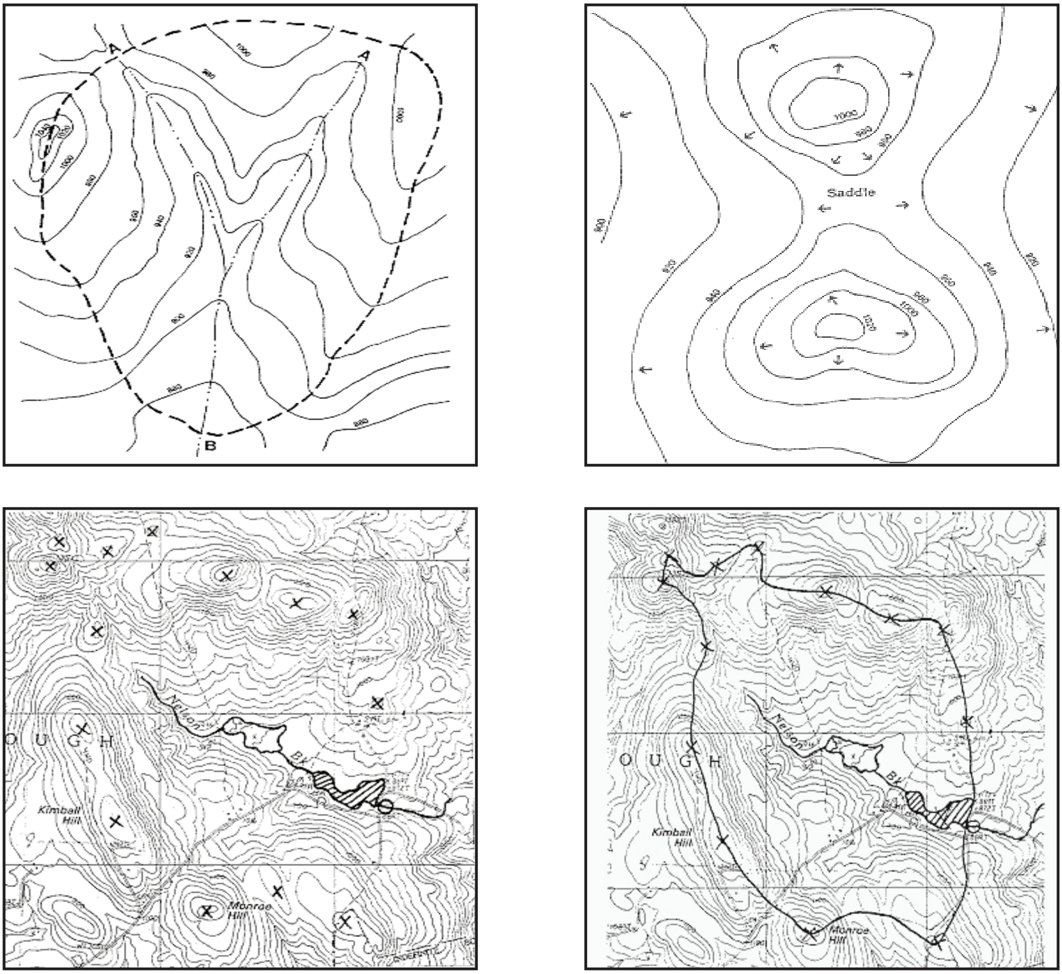

Fig. 1. Delineated map of a watershed and flow direction and watershed boundary

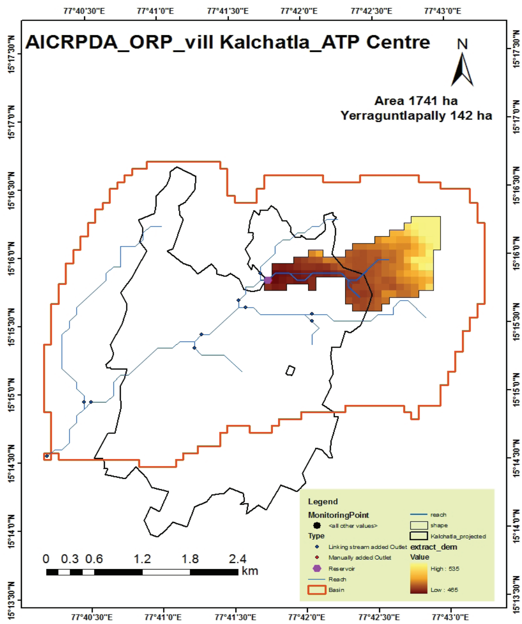

Fig. 2. Kalchatla, District Kurnool, adopted village delineated in to a micro watershed (area under interventions 142 ha of Yerraguntlapally)

Conclusions

Delineation of the adopted village into a microwatershed, either using Topo sheet or automatic delineation using digital elevation model (DEM) using GIS has been described in this chapter. Maximum moisture conservation and utilization is possible in this method and helps in reducing the erosion control, stabilizes the water ways, augments groundwater recharge, helps in addressing the intermittent dry spells, enhances fodder production, increases in agricultural production and enhances the livelihoods of the farmers.

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Establishment of Farm Machinery Custom Hiring Centers

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Food security of growing population is the major concern in India. This calls for improved production, which can be realized by enhancing input and energy use efficiency in agriculture through farm mechanization. However, a major chunk (85%) of the landholders falls in the category of small and marginal category in the country. So, small farm mechanization in long run is a major challenge for the planners. The main reasons for low agricultural productivity with small and marginal farmers is poor resource base, non-adoption of improved technologies and lack of support services and enabling mechanism. Mechanization of agricultural field operations sooner than later is the need of hour in present Indian agriculture. Mechanization of agriculture, of course, has some constraints and limitations. Earlier efforts under various national programmes in the area of farm mechanization have registered around 15-20% higher productivity in various crops at field level apart from 30 % savings in cultivation cost. Farmers owning less than 2 ha of land are not finding viability of owning costly farm implements and machinery as they are capital intensive. Establishing Custom Hiring Centres (CHCs) with expensive farm implements in villages is an important strategy to meet machinery needs of farmers particularly from small and marginal sections. CRIDA has established more than 151 Custom Hiring Centers of farm implements across all ecological regions in India under National Innovations in Climate Resilient Agriculture project (NICRA), an ICAR Flagship Platform. Apart from that, many of the State Government Agencies, NGOs and other entrepreneurs have established and are operating these Custom Hiring Centers in various parts of the country. A positive impact is seen across the country on these CHCs established by different organizations. However, still there are operational and technical constraints involved in establishing these centres. This paper provides the critical review over the establishment, operationalization and management of CHCs.

Mechanization of agriculture, of course, has some constraints and limitations. Few of them are illustrated below:

i. High initial cost often prohibits individual ownership especially amongst marginal, small and small-medium farm holders.

ii. Limited use of machinery restricted to operational seasons.

iii. Lack of knowledge in the aspects of operation, maintenance and repair of equipment.

Due to the above limitations, farmers are thinking to hire the equipment rather than maintaining them forever. In this context, different models have come up in recent past to keep the equipment at the farmer vicinity for hiring purpose. In addition to that, during last few decades, climate change and its impacts such as frequent droughts, high intensive rainfall and extreme weather events have condensed the number of workable days which has increased pressure on farming community to opt for suitable alternative apart from labour problem. Keeping these factors in view, many new crop production technologies with appropriate machines have come into prominence. Establishing Custom Hiring Centers (CHCs) with expensive farm implements in villages is an important strategy to meet machinery needs of farmers particularly from small and marginal sections. Custom hiring of farm machines was first introduced in Indian agriculture in the early decades of 19th century. Organized custom hiring to promote multi-farm use of agricultural machinery was made in mid-1960 when Agro-Industries Corporations (AIC) were established in the states. Custom hiring of farm implements got further boost when Government of India, in 1971, launched a scheme to set up agro-services centers all over the country. In fact, many states started the Agro Service Centers through the State Agro Industries Development Corporations with initial focus on land development machinery only. Hiring of tractors, dozers and levellers, mini excavators, cranes has been widely practiced by farmers to develop their lands apart from supplying other related agricultural machineries. However, not much impact on mechanization at farmer's level has been observed.

Sharma (1974) in his study on custom hiring services and agricultural resource productivity opined that the small and marginal farmers, who could not purchase machinery due to the price considerations, certainly were not in a position to avoid its use for some of the operations of cultivation. There is a need for accelerating the growth rate of agricultural production from about 3.7 per cent to about 7.18 per cent annually and to achieve this, productivity of marginal, small and medium category farms will have to be increased substantially meeting their needs of additional farm power and machinery through custom service is an important element of any strategy in this direction (Srivastava *et al*., 1999). While a large number of farmers in Punjab, Haryana, Western U.P., West Bengal were getting productivity between 8-12 tonnes/ha, it was not impossible to get productivity of about 5-6 tonnes/ha and 2-3 tonnes/ha in other irrigated areas and rainfed areas, respectively. Adequate farm power and high capacity farm implements can help in timeliness of operation and in maximizing utilization efficiency of other inputs as well as reducing losses in storage, processing, handling and transport. It is felt that the tractor was not a scale-free technology like seeds and fertilizers, which implied that the purchase of tractor was only justified if there was sufficient work throughout the year besides the usual field operations (Bhatia *et al,* 2000). Therefore, the producers, landowners or farm managers who do not have the capital, time, or desire to perform machinery operations themselves, hiring a custom operator to perform machinery operations was an alternative method of obtaining machinery services (Beaton *et al*. 2003). For others, custom hiring in farming may be a method to spread fixed costs of machinery over more acres, reducing per unit costs and increasing cash flow. Hence, the role of implements and machinery in crop production is emphasized by saying that the demand for agricultural machinery in future would be for high capacity crop production equipment mainly to be used on a custom hiring basis and on a commercial farm where the agriculture is becoming increasingly commercialized and where focus is on saving money, time and labor (Nagarajan *et al,* 2004).

The study on economic analysis of custom hiring of combine harvesters concluded that the combine harvesters were introduced due to the labor shortage particularly on harvesting season and uncertain weather conditions and these were being popularized and adopted by all categories of farmers in the North-Western Indo-Gangetic plains of India. It has been envisaged that farmers can benefit from technological developments in terms of large machines performing farm operations (Thakur *et al.* 2004). During the discussion on certain issues of custom hiring of agricultural implements in the Malwa region of Madhya Pradesh, it is found out that the custom hiring enterprise spreads equipment ownership costs over larger area (Ranade *et al*. 2006). The farm size, availability of labor and custom services, crop selection and cultural practices, all affected selection of an optimum equipment set and ultimately the number of equipments necessary for farming. Thus found that custom hiring centres widened the scope of providing better implements rather than those already owned by individual farmers. Some of the initial problems in farm mechanization in India has been the small and scattered size of farm holdings, financially challenged farmers, lack of awareness among the marginal farmers and dominance of dry land agriculture (Sarkar *et al*. 2007). The need for diverse agricultural mechanization scenario in India is felt due to the country's agro-ecological diversities such has high population density and socio-economic disparities (Singh *et al*. 2004). Tractor density in different states varied from 1.92/1000 ha in Assam to 71.43 tractors per 1000 ha in Punjab, with an all India average of only 17.03 tractors per 1000 ha. A study was conducted to evaluate the contribution of Cooperative Agro Machinery Service Centres (AMSCs) towards improving the economic viability of farming in Punjab (Sidhu and Vatta, 2012). Thus, found that the operations of the AMSCs were economically viable as the service centres generated profits to the extent of 2 to 30 per cent of the annualized costs.

Under NICRA, it was felt that there is a need to establish CHC in villages to overcome advarse impacts of climate change through adoption of relevant farm equipment (Srinivasa Rao *et al.* 2013). In this project, management of CHC through village climate risk management committee (VCRMC) vis. a promising model to involve rural people in to the system for decision making in day to day operations. A study was conducted to evaluate the performance of Cooperative Agro-Service Centres (CASC) operative in the cooperative sector of Punjab for providing farm machinery services. An increasing level of participation of agro-service centres has been revealed through their acquisition of large numbers of farm machineries for custom hiring. The CASCs have been found using both borrowed as well as owned funds for purchase of farm implements (Chahal *et al.* 2014). Subsidy provision acts as a safeguard against the risk involved in under-usage of machinery being purchased by the CASC in the initial years. The income of the sample CASCs increased steadily with financial support extended to such centres in terms of subsidy on one hand and increasing reach on the other hand.

A study on accessibility of farm machinery services through CHC for small and marginal farmers in Karnataka state revealed that the performance of CHCs in Raichur district have greatly enabled small and marginal farmers for performing timely operations at lower cost (Hiremath *et al.* 2015) . The CHCs have helped to increase the productivity and income of small and marginal farmers to the extent of 10 to 15 percent. These examples show that, there is a much scope for improving the performance of CHCs for the benefit of small and marginal farmers. It is well understood that no particular model meets the requirement of different ecosystems. Hence it is suggested to bring a policy for supporting the CHCs on location specific and also for different client needs with backend support for its sustainability (Srinivas *et al* 2017).

Establishment of custom hiring centres under NICRA project and CRIDA's earlier experience

Custom hiring is an approach with an immense potential to change the farm mechanization landscape of the country. With increased participation of stakeholders cutting across the farmers to the entrepreneurs with financial agency backstop and by supplying all equipments for entire life cycle of a crop sequentially, success can be evident at field level in terms of productivity enhancement at reduced cultivation cost. System of giving the implements on hiring basis is not new in India and has been practiced for many years but on individual implement basis. Structural arrangement for the same by keeping more implements at one place to meet requirements of many operations has started just a decade back. Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad established the CHCs in nine locations based on different cropping systems throughout the country during the years 2003-2007. Some of them are working till date and a few got closed because of technical issues. The impact was seen in many villages through increased number of implements for different agricultural operations. Enthusiasm among the rural farming community to purchase machinery on individual owner ship basis reduced profits of these CHCs leading to less number of machineries available. CHC under different formats was established in different states with the help of funding from state exchequers, banks and other cooperative agencies. The current status of custom hiring sector in India is only in selective interventions predominantly land preparation, sowing, spraying and harvesting with appropriate machinery. Sub-Mission on Agricultural Mechanization (SMAM) is one such initiative towards achieving this objective. Custom hiring facilities for agricultural machinery is one of the major components of this mission. State governments of Karnataka, Andhra Pradesh, Madhya Pradesh and Punjab have been promoting Custom Hiring on Public Private Partnership basis through training, demonstration and financial incentives. Different models of CHCs are discussed below:

NICRA model of CHCs for small farmers: (A project based model for small holding farm)

In order to address the climatic vulnerabilities of the selected villages, different interventions were planned under four modules. However, the specific intervention under each module for a particular village was need-based and finalized on the basis of climatic vulnerability and resource situation. The four modules were natural resource management, crop production, livestock and fisheries and institutional interventions. For demonstrating various climate resilient interventions related to natural resource management such as in-situ moisture conservation, biomass mulching, residue incorporation instead of burning, brown and green manuring, water harvesting etc, appropriate implements were identified.

Keeping in view of the needs of small farmers, 151 CHCs were established across different ecological zones in India under NICRA project. All these centers mainly focused on small farm mechanization based on location specific needs. Central Research Institute for Dryland Agriculture (CRIDA) took the responsibility of planning, coordination, and monitoring of the programme at national level. Eight Zonal Project Directorates (ZPDs) and concerned State Agricultural Universities (SAUs) were involved in coordinating the project in their respective zones. At district level, selected KVK was responsible for implementing project in selected village through farmer's participatory approach. Interventions were mainly focused on addressing climate related constraints and not on general technology transfer.

Village Climate Risk Management Committee (VCRMC)

A VCRMC representing all the categories of farmers in the village is formed with the approval of gram sabha. This committee is involved in programme planning and implementation. The committee plays a vital role in the selection of need based equipment useful for the village. VCRMC participates in all discussions to finalization of interventions, selection of target farmers and area. Liaison with gram panchayat and local elected representatives helps in financial transactions under NICRA including maintaining farmers' contributions for different activities and handling of payments recovered from custom hiring centres.

Selection of target Village: Village was selected based on vulnerability of agriculture to climatic variability. Highly vulnerable village gets priority in selection. Using secondary/ published data, village with relatively more climatic variability like prolonged drought, dry-spells, extreme rainfall events, hailstorms, extreme temperatures, cold and heat waves, frost, flood, seawater inundation, etc was selected.

Selection of machinery: By following the bottom up approach and in consultation with the community, list of farm implements for crops grown in the particular village was prepared by the interventions of local farmers, KVK resource persons, SAUs and CRIDA scientists. Lists were finalized for each CHC based on budget availability and location specific needs of the community concerned. After finalization, list was sent to the coordinating unit at CRIDA, Hyderabad. VCRMC played a key role in identification of the machinery in all the KVK. Typical machinery selection is given below which is located in Village Titihara, District- Chitrakoot, Uttar Pradesh, India.

Table 1. Name of Implement

S. No	Name of Implement	Number
1	Rotavator	1
2	Seed cum fertilizer drill	1
3	Land leveler	1
4	Multi crop thresher	1
5	Tractor drawn reaper	1
6	Seed grader	1
7	Paddy reaper	1
8	Knapsack sprayer	1
9	M. B. plough/disc plough	1
10	Ridge maker	4
11	Duster	4
12	Motorized knapsack mist blower	1
13	Sprinkler set with diesel engine	1
14	CFTRI mini dal mill	1
15	Soil sampling augar	1

Financial support: Each CHC was initially supported by NICRA with an amount of Rs. 6.25 lakh sanctioned to each KVK for the purchase of identified implements. Apart from that additional money is also given from time to time based on the need of the centres for smooth running.

Objectives of the custom hiring centers

i. To make available various farm machinery / equipments to small and marginal farmers at lower rental cost.

ii. To meet timeliness operational needs of the farmers through appropriate machinery.

iii. To facilitate farmers on application of the innovative crop management practices with specific machinery.

iv. To increase the productivity and cropping intensity by increasing the power availability at farm level.

Fixation of hiring charges: VCRMC has the option to decide hiring charges in consultation with the local farmers. Money received through hiring of machineries is deposited in the VCRMC account.

Training to field staff and farmers: Necessary trainings on skill development for operation and maintenance of the machinery are imparted to the resource persons and farmers at CRIDA and at CHC centres.

Fig. 1. CHC at Bhuj, Gujarat

Farmers' perception about the CHCs

- It provided the equipment for agricultural operations to accomplish within timeframe.
- It created additional employment for skilled labour.
- It helped in application of new technologies at field level through availability of effective machines at low rentals.
- Reduced drudgery and also attracted youth towards agriculture.
- It increased the cropping intensity.
- It reduced the cost of cultivation.
- It met the timeliness of major agricultural operations and saved inputs.

Merits of NICRA model CHCs

- Available extension network and technical expertise of KVKs were utilized for technical backstop.

- By forming Farm machinery Service Centers/Farmers Committee, requirements of individual village/agro-climatic zone were assessed and use of equipments was tailor made as per requirement/demand.
- Revenue generation was ploughed back to the society.
- Operation, repair and maintenance were taken care off.

Evaluation of farm machinery custom hiring centers

After establishing the CHCs, the high level monitoring committee constituted for NICRA project recommended CRIDA to evaluate the performances of CHCs. Accordingly, scientists of CRIDA and Central Institute of Agricultural Engineering selected 22 KVKs for their performance evaluation in terms of viability, sustainability, economics, status of working and other social factors. Sample selection was based on their income generation, extent of machinery utilization, cropping system, location and other social factors. Data collected through a well defined questionnaire and from personnel interaction of KVK staff, VCRMC and user farmer groups has been shown in following Table 2.

Table 2. Details of CHCs evaluated

Zone	KVK	State	Revenue generated (Rs)from June 2012 till March 2016	Area covered (ha)	No. farmers covered
I	Faridkot	Punjab	228750	1443	928
	Yamunanagar	Haryana	50400	147	233
II	Malda	West Bengal	40112	195	1618
	Saran	Bihar	73390	1069	1610
IV	Kushinagar	Uttar Pradesh	70200	595	2428
	Chitrakoot	Uttar Pradesh	8270	154	437
V	Ratnagiri	Maharashtra	36250	381	440
	Amravati	Maharashtra	222496	3658	3424
	Rangareddy	Telangana	45020	2454	1038
	Nalgonda	Telangana	32550	209	167
	Srikakulam	Andhra Pradesh	10165	209	200
	West Godavari	Andhra Pradesh	11020	66	162
	Khammam	Telangana	20322	118	83
VI	Kutch	Gujarat	22100	313	389
	Jodhpur	Rajasthan	20650	358	418
	Rajkot	Gujarat	21823	904	978

Zone	KVK	State	Revenue generated (Rs)from June 2012 till March 2016	Area covered (ha)	No. farmers covered
VII	Datia	Madya pradesh	82701	990	1052
	Morena	Madya pradesh	134915	997	2052
	Balaghat	Madya pradesh	18650	195	192
	Kendrapara	Odisha	35484	976	782
VIII	Namakkal	Tamilnadu	816231	482	1194
	Kolar	Karnataka	36950	376	263
		Total	**2038449**	**16289**	**20088**

Though the different types of implements ranging from 6 to 15 types are kept at CHCs, only few are popularized in hiring system, thus they generated more revenue compared to other implements. Centre wise details have been shown given in Table 3.

Table 3. Major crops and popular implements under CHC

Zone	KVK	Major crop	Most popular implements under CHCs
I	Faridkot	Paddy, Wheat, Maize and Cotton	1.Rotavator 2.zero till drill 3.Bed planter
	Yamunanagar	Paddy, Wheat and sugarcane	1.Laser land leveller 2. Bed planter 3. Turbo seeder
II	Malda	Cotton, Wheat and Maize	1.Rotavator 2.Multi crop thresher
	Saran	Rice, wheat and maize	1.Rotavator 2. Zero seed drill
IV	Kushinagar	Paddy, Maize, Wheat and Sugarcane	1.Paddy transplanter 2.Zero till drill
	Chitrakoot	Wheat, Jowar, Pigean pea and Gram	1.M.B.Plough 2. Seed cum fertilizer drill

Zone	KVK	Major crop	Most popular implements under CHCs
V	Ratnagiri	Paddy, Groundnut and Gram	1. Power tiller 2. Reaper 3. Thresher
	Amravati	Cotton, Soyabean and pigeon pea	1. Rotavator 2. Seed cum fertilizer drill
	Hyderabad	Cotton, Red gram and vegetables	1.Rotavator 2. Multi crop planter
	Nalgonda	Cotton	1.Rotavator
	Khammam	Cotton and paddy	1.Drum seeder 2. Multi crop thresher
	West Godawari	Paddy	1.Drum seeder
	Srikakulam	Paddy	1.Drum seeder
	Kutch	Cotton, wheat and jowar	1.Rotavator 2. Seed cum fertilizer drill 3.Multi crop thresher
VI			
	Jodhpur	Bajra, Moong nad Moth	1.Seedcum Fertilizer drill, 2.sprayer and duster
	Rajkot	Cotton, Groundnut, Wheat and Gram	1.Rotavator 2.Planter
VII	Datia	Wheat, Soyabean and Gram	1. Cultivator 2. Rotavator 3. Seed drill 4. Multi crop thrsher
	Morena	Wheat, Pigeon pea, Green gram, Maize, Black gram and Barley	1. Tractor drawn land leveller 2.Zero till drill 3. seed cum fertilizer drill 4. Turbo seeder
	Balaghat	Paddy, Wheat and Vegetables	1.Rotavator 2.Zero till drill
	Kendrapara	Paddy, Groundnut Gram and sugarcane	1.Power tiller 2. Thresher 3.Sprayers
	Namakkal	Paddy, Groundnut	1.Cultivator 2. Rotavator
VIII	Kolar	Groundnut and Tomato	1. Rotary weeder 2. Groundnut decorticator
		Total	**22**

Among the selected CHCs, about 48 % of them generated the revenue below Rs. 20,000/- and 30 % of the CHCs generated within the range of Rs. 20,000/- to 45,000/- and the remaining 22 % of CHCs generated the income above Rs. 45,000/- and the distribution is shown in the Fig.2. Since the revenue generated among CHCs is considered as one of the successful parameters in smooth running of centre, it has been represented graphically below in Fig. 2.

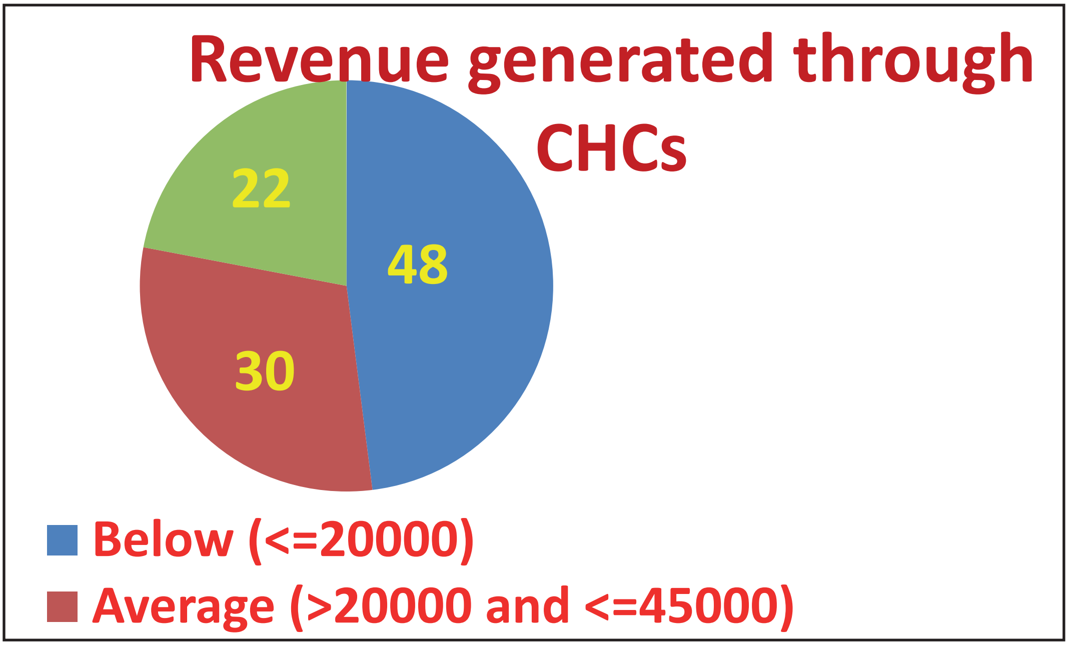

Fig. 2. Distribution of CHCs based on average revenue generated/year through CHCs

CHC that generated revenue below Rs. 20,000/- is considered as below average centre since the income is not enough to cope up with minimum maintenance of the CHC. Average grade centre is one which generated the reenue above Rs.20,000/- and below Rs. 45,000/- as this fund is sufficient to marginally maintain CHC. Centres, that generated an income above Rs. 45,000/- was considered sufficient to run and attend repairs of machinery in CHC. However, this economy is limited to this NICRA model as the low rental rates are fixed by many KVKs for the benefit of the poor farming community in their region and necessary financial support is also given by the project.

Following points related to execution of the centres were observed during the evaluation:

i. All centers were run by VCRMC with the help of KVK staff.

ii. Many of the centers had fixed low rental rates because of local farmers' pressure which is not viable for centre's sustainability.

iii. Repair and maintenance of the equipment was not attempted properly by some of the centers because of which the machinery was kept idle though the demand was there.

Advantages observed during the evaluation of NICRA CHC

- Stakeholders have expressed that the CHCs were useful for village.
- Mechanization in critical operations was improved because of availability of high cost machinery at their village level.
- Cropping intensity was also increased in some of the areas.
- Some of the critical agronomic recommendations like intercropping and residue incorporation were taken up in time with advanced machinery.

Specific advantages observed in terms of coping with the climate variability

- Mechanization in critical operations improved with access to appropriate machinery.
- Zero tillage machines of CHCs impacted on crop productivity (wheat, maize, rice) because of timely sowing and energy and water saving.
- Crop residue burning was reduced with the introduction of rotavator, mobile chipper shredder and recycled back into the soil for improving soil organic carbon and soil health.
- Timely harvesting and threshing in unforeseen climatic conditions.
- Cropping intensity had also increased in some of the areas because of timely planting, inter-culture & harvesting operations.
- Some of the critical agronomic recommendations like intercropping and residue incorporation, paired up with row planting are taken up in time with the help of

Fig. 3. Residue incorporation through mobile shredder, Zero tillage machinery

Fig. 4. Ridger planter and castor crop

advanced machineries like multi crop planters and mobile shredders, raised bed planter etc.

- Overall profit by 20 to 30 % in addition to input savings of 25-30 %.

Constraints in CHCs of NICRA in different zones

It was also observed that; present NICRA model has following constraints which were majorly considered.

i. Maintenance cost of the equipment like rotavator, thresher, shredder was not being met through the generated revenue.

ii. Lack of permanent skilled person to look after the CHCs work and maintenance.

iii. Farmers did not take the responsibility of repairing equipments. At times, there was great delay from farmer's side in returning the equipment.

iv. Payments were not regular.

v. Demand for certain implements during peak season.

vi. Under utilization of certain equipments like reaper, power weeders etc. during off season.

vii. Demand for costly equipments like combine harvesters, boom sprayers, threshers etc.

viii. Differences among the farming community on priority use of implements.

Conclusion

It was clearly observed that the CHCs are very useful to farming community particularly for small, marginal, semi-medium farmers. In almost all cases, the generated funds not sufficient to successfully run the CHCs on long-term basis. In some cases, there was no demand for some implements which can be replaced by need based high cost machinery such as combine harvesters, multi crop threshers etc. Some of the CHCS supported by the government with significant subsidy backup are working with marginal profits but the long term sustainability will be depend on the future business volume. Apart from meeting the operational requirements, CHCs are much useful to the farmers for creating awareness on new implements. Increase in cropping intensity resulted in employment generation. Therefore, the government should extend the financial support to the extent of 50 to 90 % of total capital cost including the shed and other infrastructure facilities. At the same time an input subsidy of 50 % on rental cost should be extended to the small and marginal farmers who ever utilizes the services of CHCs which will boost the productivity and reduce the cultivation cost.

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Crops and Cropping Systems for Soil and Water Management

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Soil and water management is gaining lot of importance worldwide not just because of soil losses occurring in different regions that lead to low yields and poor income, but also due to changing climate observed in terms of unseasonal, ill distributed rainfall as well as extreme rainfall events. As efforts are on globally to make dryland agriculture competetive, plugging the losses (soil and water) issue becomes prime concern. Unless the soil is productive, manipulating crop sowings and other operations matching the weather variations is not possible. Matching suitable measures with the required site/soil management is critical, therefore soil and water management measures to improve productivity of the soil and thereby farmers' income may be focused upon. Most engineering management measures like check dams, gabions *etc*. are matched to the specific land requirement while the measures on crop lands must be mostly agronomic which is mostly a non monetary input. Agronomic measures include crops which grow close to the soil reduce the raindrop impact on soil dislodging the soil grains while cropping systems like intercropping and sequence cropping systems are for slowing down the runoff and thereby reducing the soil carrying away by runoff water.

Crops

Crop stature: A study taken up in AP on 3% slope stated that maize, a tall growing crop resulted in higher runoff (2198 litre) than the cowpea crop (1120 litre). It is found that maize-cowpea intercropping at 2:4 resulted in 38.6 % less runoff and 30.7 % less sediment loss. The farmers usually cultivate maize as one of the remunerative *kharif* crop. This crop alone is not able to reduce soil erosion under this agro-climatic condition. The farmers can go for a intercropping of traditional maize with cowpea which can reduce the soil erosion considerably in the sloping lands. Hence, the farmers can be suggested not to go for single crop like maize instead to go for inter cropping of maize and cowpea.

Cover cropping*:* Selection of crops as per the maturity durations matching with the onset of rainfall, amount and its distribution. Various maturity groups like short, medium and long duration crops ensure soil cover basically and reduce the raindrop impact.

Crop spacing: Wider spacing between crop rows is the recommendation in drylands to extract scarce soil moisture. However, this may accentuate the soil erosion due to poor crop cover.

Table 1. Site specific crops an dcropping systems and their performance with various land configurations

Crop	System	Average yield (t/ha)	
		Control	With land configuration
Sorghum + pigeonpea (Hyderabad-Alfisols)	Flat on grade and ridging later	2.45+0.58	2.91+0.72
Finger millet (Bangalore- Alfisols)	Graded border strip with 0.1% grade	2.28	3.25
Peanut (Ananthapur-Alfisols)	Dead furrows at 2.4+3.6m intervals	0.68	0.75
Sorghum (Akola-Vertisols)	Broad-bed and furrow	1.69	2.13
Sorghum (Bellary-Vertisols)	Graded farming	0.21	0.28
Corn+rice(2:1) (Dehra Dun-Entisols)	Inter-plot water harvesting	0.97+1.0	1.14+1.21
Pearl millet (Jodhpur-Aridisols)	Inter-plot water harvesting(1:1) slope on both sides	1.85	2.80
Pearl millet (Jodhpur-Aridisols)	Inter-row water harvesting (Polyethylene)	0.56	0.84

(Source: CRIDA, 1986.)

Table 2. Runoff and soil loss under different in-situ moisture conservation practices in blackgram and the yields

Treatment	Yield (kg/ha)		%runoff of rainfall producing rainfall	Soil loss (t/ha)
	Grain	Stover		
(A)Summer deep ploughing (SDP)				
Compartmental bunding 2 at 5m interval	1058	3172	18.35	0.670
Sowing across slope	1023	2897	20.50	0.690
Raised bed (70cm) width	1172	3492	13.74	0.621
Raised bed (40cm) (B) width	1243	3815	11.26	0.58
Mean	**1124**	**3344**	**15.96**	**0.64**
(B) Shallow tillage (ST)				
Compartmental bunding 2at 5m interval	846	2400	33.40	1.846
Sowing across slope	812	2400	37.45	1.975
Raised bed (70cm) width	892	2625	26.90	1.486
Raised bed (40cm) (B) width	958	2800	25.40	1.314
Control	466	1715	59.48	2.156
Mean	**795**	**2388**	**36.53**	**1.76**

Runoff events = 3; Runoff producing rainfall = 219 mm; Total rainfall during crop growth period =591.8mm (Source: Annual Report 2010-11, AICRPDA)

Growing various combination of crops and cropping systems is not sufficient as was indicated in the (Table 1) However the significance of combining the mechanical management measure with the crops and cropping systems to achieve improved yields while reducing the water and soil losses (Table 2) was highlighted.

Cropping systems

Growing two or more crops of varied durations, statures as intercrops in different row proportions during different seasons helps in reducing the velocity of runoff water. These systems include strip cropping, mixed cropping, and alley cropping. Cropping systems also include sequence/double cropping which improve crop cover.

Strip intercropping which is growing crops in the form of strips, which can interact agronomically to term it as intercropping while the management practices are carried out individually to some extent. These strips can be alternated with soil erosion permitting crops and soil erosion resistant crops. The increased reistsance to runoff in ERC results in higher volume of water percolating through soil profile, due to increased time of (on-ground) concentration. The close growing ERC strips are generally lgumes which fix nitrogen in the soil and enrich it. The canopy of the ERC also protects he soil from the beating action of raindrops. Strip cropping also helps in stabilizing crop production. Strip intercropping further categorised as i. contour strip intercropping, ii. Field strip intercropping, iii. Buffer strip intercropping, iv. Wind strip intercropping

Contour strip cropping: Growing of ERC and EPC (Erosion permitting Crops) in alternating strips of varied widths along the contours.

Field strip cropping: Growing ERC and EPC strips alternatively across the slope.

Buffer strip cropping: Permanent or temporary strips are grown on steep slopes or highly eroded field parts.

Wind strip cropping: In order to ward off the ill effects of wind, tall and short statured crops alternatively in long and straight lines across the wind direction. Besides this, alley cropping by creating perennial alleys alternated with annual crops could also considered for improving dryland productivity per unit rainfall received. Alley cropping is practiced with Leucaena leucocephala as there is yield advantage for post rainy crop in vertisols. The losses in crop yield due to association with a perennial component is compensated with the adition of oppings from the tree component.

Conclusion

Combination of crops and cropping systems matching with the rainfall situation and the mechanical measures of soil and water management on crop lands with the support from engineering management measures in the non arable crop lands can improve the yields for doubling the farmers' income.

Strategies to upscale

Keeping the monetary requirement of any measure and it's site specific implementation and local dietary patterns in view, suitable crops of different statures and durations and cropping systems including intercropping and sequence cropping are to be taken up for demonstrations and support services like suitable implements, seed and package of practices are to be provided. Capacity building of farmers and rural unemployed youth may also be taken up for maintenance and upkeep of implements.

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Horticulture based Farming Strategies for Augmenting Incomes of Vulnerable Afro- Asian Dryland Communities

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Climate change, land /soil degradation (nearly 70 m ha) with multiple nutrient and water deficiencies, declining ground water table and poor resource base of the farmers are principle constraints for low and unstable yields in rainfed areas. There is a need to enhance the productivity of rainfed crops from at least 1 to 2 T to meet the food requirements by 2022 AD. Therefore integrated farming systems assumes a greater importance for sound management of farm productivity, reducing environmental degradation, improve the quality of life of the resource poor farmers and sustainability in rainfed regions. Depending on the scale of the analysis, a farming system can encompass a few or many millions of households. In a farming system, the farm family is also intimately linked for its holistic approach. It is based on the ecological, economic and demographic considerations. Farming systems provide for better utilization of resources and provide for maximization of returns to the owned or internally generated resources.

Of the 1.2 billion people worldwide living in dollar poverty, over 43 percent are found in South Asia. Of these, the vast majority live in rural areas. Despite improvements in national food security over the last three decades, benefits have not yet reached the entire population of the region and FAO estimates that 254 million people are still undernourished. Indicators of other dimensions of poverty, such as female illiteracy (59 percent), child mortality (89 per 1 000 in children under five years), and child malnutrition (51 percent) 5, also point to extensive poverty. The rural poor are particularly vulnerable to droughts, floods and other natural disasters. According to IFAD estimates, about 66 percent of the vulnerable population in India are small farmers and 2 percent are artisanal fishing families. Women are particularly disadvantaged; female-headed farm households have far lower average incomes than equivalent male-headed farm households.

Horticulture in India is a major producer of fruits and vegetables in the world. For the holistic development of the horticulture sector, a Centrally Sponsored Scheme called the National Horticulture Mission (NHM) was launched in 2005-06. The objectives of the Mission are to enhance horticulture production and improve nutritional security and income support to farm households and others through area-based regionally differentiated strategies. Crops such as fruits, spices, flowers, medicinal and aromatic plants, plantation crops of cashew and cocoa are included for area expansion, whereas vegetables are covered through seed production, protected cultivation, integrated nutrient management/ integrated pest management (INM/IPM) and organic farming. The impact of the Mission can be seen in the increasing area and production of fruits and vegetables. Technology Mission for Integrated Development of Horticulture in the North Eastern States (TMNE) covers the hill States and North Eastern States of India. Apart from introduction of improved production technology in traditional crops, a significant contribution of the Mission has been in the promotion of commercial cultivation of potential crops, namely citrus, fruits, banana, pineapple, strawberry, kiwi, apple, passion fruits; anthuriums, roses, liliums, orchids and other cut flowers; and high value vegetable crops. The most remarkable development under the scheme has been the expansion of area under specific crops in the States and in clusters which will facilitate easy marketing access in the future.

However for a comparison about 100 million hectares of agricultural land in South Africa is considered. Out of which 14 million receive sufficient rainfall for viable arable farming. The remainder of the land is used for extensive grazing (72 million hectares), nature conservation (11 million hectares), and forestry (1 million hectares). Dry land cultivation is practiced on 11.2 million hectares and irrigated agriculture occupies slightly more than 1.2 million ha that produce 25 to 30 percent of the country's agricultural output (AAS 2007). Agriculture contributed about 3.5 percent of the country's growth domestic product (GDP) in 2002. Kwazulu Natal province made the largest contribution to agricultural value added (VAD) (28.3 percent) followed by the Western Cape (22.6 percent). Three categories of products contributed to the agricultural GDP, namely: (1) field crops; (2) horticultural products; and (3) livestock. Over the past two decades, the average contribution to gross VAD of the agricultural sector was about 37 percent, 20 percent, and 43 percent from field crops, horticulture and livestock, respectively (AAS, 2007).

Watershed based farming system

The land use system that results in an efficient, optimized and sustainable use of natural resources including biotech, socio-economic and related infra-structural resources. Farmers in rainfed agriculture are following mixed farming practices to spread the risk and produce of various commodities in watersheds. With evaluation of market oriented farming most of the earlier production systems gave way monoculture of arable crops. With appropriate farming systems majority of the needs of the farmers can meet within the production system. Livestock forms an integral part of the farming systems in most rainfed areas. Neglect of fodder production resulted in acute fodder scarcity leading to poor livestock health and quality. Keeping the above facts in view, the rainfed farming system model for small and marginal farmers (1-2 ha) should include the components of

- ❖ Arable crops (cereals, oilseeds, pulses) to meet the food requirement of the family.
- ❖ Fodder crops on degraded lands and field boundaries to meet feed needs of the cattle. Economic bushes for higher income in marginal lands.

- ❖ Horticulture crops (fruit and vegetable trees) to maintain nutritional security of the farm family besides earning some income to meet felt needs of the farm family.
- ❖ A well-developed farmstead area covering small and large ruminants (diary, sheep/goat, poultry, piggery, apiry) to provide year round flow of small income and for higher employment opportunities.

The area in the model farm should be systematically treated with field bunds across the slope covering with multi-purpose trees / bushes to reduce the dependence on external inputs (chemical fertilizers and feed). Creating farm ponds at strategic location can do water harvesting.

Alternate land use systems

Agroforestry (AF) is a collective name for land-use systems in which woody perennials (trees, shrubs, palms, bamboos etc.) are deliberately grown in association with herbaceous plants (crops, pastures) or livestock, in a spatial arrangement, a rotation, or both; there are usually both ecological and economic interactions between trees and other components of the system" It can be classified into agri silviculture, alley cropping, agri horticulture, sivi pasture and horti pasture etc., depending on nature of the component in the system. Tree farming, social forestry are other alternative land uses which are meant to improve the degraded natural base besides providing ecionomic products to the community. It is aimed to optimize the use of resources through recycling, internalize the input production, reduce the risk and conservation of natural resources. It reduces the erosivity of rainfall and erodability of soil through dissipation of energy of raindrops by canopy and improves the soil organic matter, physic-chemical and biological properties of soil. Alley cropping with leucaena /Glyricidia hedges and grass barriers have been found effective in controlling erosion upto 30% slope under humid, sub-humid and subtropical climatic conditions.

Agri-horticultural systems: Among various land use systems, agri-horti system is most important in terms of economic returns to the farmers and also farmers preference. The Agri-horti-silvi-duckery-fishery system studies North East India showed that multi enterprise model comprising cereal crops, pulses, oil seeds, horticultural crops such as mango and pineapple, vegetables crops and livestock components of duckery, piggery, and fishery with harvesting structures in 1 ha land gave 5 times more profitable than traditional mono crop rice cultivation.

Horti-pastoral systems: Horti pastoral system is a combination of fruit trees and pasture or legume. It is ideal land use option for degraded lands.

Slope agriculture land technology: The method of growing seasonal and perennial crops in 3m to5m wide bands between contour rows of N fixing trees is called as Slope Agricultural Land Technology (SALT). The N fixing trees are thickly planted in double rows to make hedge rows. When hedge is 1.5 to 2m tall, it is lopped to about 40cm height and the loppings are placed in alleys to serve as mulch cum manure. This practice improves soil organic matter and other physic-chemical properties in the hill and mountain system

Agri-Silviculture system: It is recommended for land capability class IV with annual rainfall of 750 mm. A large number of tree-crop combinations, particularly of N, fixing trees with sorghum, groundnut, castor and pulses were evaluated in Alfisols and Vertisols.

Tree based farming: The marginal lands or the lands, which are not capable of supporting the field crops, can be best converted into the tree-based farming. With the treatment measures, soil fertility and moisture level can be enhanced. With the availability of water for protective irrigation orchards, agr-horti-forestry becomes viable option in such area.

Live fence rows: Fence row areas are important in most uplands of small farm size in rainfed lamds. They are usually planted to a species of legume (Leucaena leucocephala or Sesbania grandiflora) in wet areas and Zyziphus, Hibiscus, Glyricidia etc. species in dry areas . The former serve as a source of human food and animal feed, with leaf protein approaching 6 per cent. All are used for firewood and green manure.

Table 1. Trees as hedges: Live hedges taken by the farmers as given:

Common name	Botanical name	Uses
Sisal agave	*Agave sisalana*	Non-browsable, drought-resistant, yields twines, used in ship-cordage, webbing and sacking, paper making, hard-ware production, also useful in erosion control (Gully checks)
Shkikai	*Acacia rugata*	Yields fuel, reduces soil erosion and serves as cleaning powder
Agave	*Agave cantala*	Non-browsable, checks soil erosion, of commecial value, used in rope making, cordage, mats, twines and nets
Molucca bean	*Caesalpinia crista*	Reduces soil erosion
Coral tree	*Erythrina variegata*	Non-browsable, soil and water conservation
Thor	*Euphorbia sp*	Non-browsable, of medicinal value
Jatropha	*Jatropha carcus*	Non-browsable, soil and water conservation
Lantana	*Lantana camara*	Non-browsable, resistant to adverse conditions, im-proves fertility of exhausted areas and rocky gravelly or hard infertile soil, used in soil conservation, adds humus, green manure, convertible to compost
Kewada	*Pandanus odoratis-simus*	Non-browsable, soil binder, controls erosion from wind and water, shelter belt to sand drifts, of food value, used in making paper, ropes, cordage, hats, baskets, umbrellas and fancy articles, roots for brush and basket making
Horse bean	*Parkinsonia aculeate*	Used as fuel, fodder, paper making, of medicinal value
Vilayati babul	*Prosopis juliflora*	Immunity to grazing, yields firewood, fodder.

Crop based farming systems: The farming system module initiated in 1.14 ha area of watershed at CRIDA comprises arable cropping of sorghum + pigeonpea, castor + cluster bean and sole pearl millet and pigeonpea (40.9%) grasses (9.9%) agro-forestry of aonla + cowpea, pongamia + cowpea and custard apple (28.62%). Bushes of curry leaf and jatropha (9.65%) are also included.

Crop diversification

Floriculture with marigold can reap higher profitability. In rabi sorghum dominant areas, chillies + cotton (1:1), chillies + onion can be practiced in lieu of chillies at 60 cm row spacing during kharif, then sowing of cotton in the intra row of chillies.

Medicinal and Aromatic Plants: Cultivation of high value and low volume crops for dyes, medicines and aromatics is economical in rainfed lands. They also played a vital role in sustained use of degraded lands. These perennial and annuals with plants mostly of bushy nature. The advantage of bushes over larger perennials is that the former offers less competition to associated crops. The promising plants for cultivation in drylands are dyes like Indigo (*Indigofera tinctoria* L.), Henna (*Lawsonia innermis* L.) and Bixa (*Bixa orellana* L.), Meidcinal plants like Ashwagandha (*Withania somnifera* (L.) Dunal), Senna (*Cassia angustifolia* Vahl.), Mucuna (*Mucuna pruiens* (L.) Spreng), lemon grass (*Cymbopogan winki* (DC) Stapf), Palma rosa (*Cymbopogan martini* (Roxb.) Wats), and sweet basil (*Ocimum basilium* L.).

South Africa may be subdivided into a number of farming regions according to climate, natural vegetation, types of soil, and the type of farming practiced. The principal cropping regions are the summer highveld plateaus of Gauteng and Free State, as well as the highveld and midlands of Kwazulu Natal and winter rainfall region of the Western Cape. The Joint Agriculture and Weather Facility of the National Oceanic and Atmospheric Administration (NOAA) of the United States determined four climatic zones for South Africa based on crop areas and climate profiles: the steppe (arid), desert, sub-tropical wet and sub-tropical winter rain zones. Due to the history of apartheid policies, agriculture in South Africa is highly dualistic; a commercial sector located in the “former white South Africa” is run predominately by white farmers, while a subsistence sector is located in the former homeland areas and run by black farmers. The institutional infrastructure of agriculture differs in quality, availability and accessibility between commercial and subsistence farms (Coetzee and Van Zyl 1992). The commercial sector is the dominant form of agricultural production in South Africa. It is large-scale, commercially oriented, capital-intensive, export-led, and it accounts for 90 percent of total VAD in agriculture and covers 87 percent of the agricultural land. The average size of commercial farms in South Africa is estimated to be about 1,200 hectares under private ownership, and there are about 46,000 commercial farm units in the country. In contrast the subsistence sector is an impoverished sector, dominated by low-input, labour intensive production. Despite the land reform initiatives put in place since 1995, the estimated 3.4– 4.8 million smallholders are predominantly settled in the former homelands and produce on the remaining 13 percent of the agricultural land (17 million hectares) (Feynes and Meyer 2003) for semi-subsistence purposes. Land holdings in the former homelands are generally very small (Groenewald and Nieuwoudt 2003) and are under a communal land tenure system. Only 3.7 percent (47,486 hectares) of the total irrigated land in South Africa is under smallholder agriculture. While there is high potential for veld grazing in these areas, stocking currently exceeds the carrying capacity of the land in most areas, and overgrazing has severely affected the quality of arable land in many areas. Poverty in rural areas is associated with agricultural policies, which have persistently marginalized small-scale black farmers by curtailing their access to resources such as land, credit and technical know-how (Coetzee and Van Zyl 1992).

Farm survey data from Kenya and Zambia show that fresh fruits and vegetables, dairy, and other forms of animal production are rising as a share of total farm production, and that this trend is associated with improvements in the reliability of food markets (Jayne *et al.* 2010). In Kenya, horticulture production as a share of total farm production is especially high on small farms, suggesting that land-constrained households may, at the margin, be devoting more of their scarce area to crops with relatively high returns (Kimenju and Tschirley, 2009).

Table 2. Farming operations in different farming systems

	Forest fallow system	**Bush fallow system**	**Short-fallow system**	**Annual cultivation system**	**Multiple cropping system**
Labor-land ratios (reflecting pop. density)	Low →				High
Land preparation	no land preparation	use of hoe to loosen soil	plow	animal-drawn plow	animal drawn plow and tractor
Fertilization	ash	ash	manure, green manure	green manure, inorganic fertilizer	Intensive use of inorganic fertilizer
Weeding	minimal	required as length of fallow decreases	weeding	intensive weeding	intensive weeding

Source: condensed and adapted from Binswanger and Pingali (1988).

Farming systems and their characteristics

Each individual farm has its own specific characteristics, which arise from variations in resource endowments and family circumstances. The household, its resources, and the resource flows and interactions at this individual farm level are together referred to as a farm system. A farming system is defined as a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate. In attempting to combat hunger and poverty, developing countries face the challenges of identifying specific agricultural and rural development needs and opportunities, and focusing investment in those areas where the greatest impact on food insecurity and poverty could be achieved. The delineation of farming systems provides a useful framework within which appropriate agricultural development strategies and interventions can be determined, as by definition, they group farm households with similar characteristics and constraints. Only a limited number of systems are delineated within each region (and in this Summary, only the most important of these systems are discussed), leading inevitably to a considerable degree of heterogeneity within any single system. However, the alternative of identifying numerous, discrete, micro-level farming systems in each developing region would detract from the overall impact of the analysis. The classification of the farming systems, as specified herein, has been based on a number of key factors, including:

i) The available natural resource base;

ii) The dominant pattern of farm activities and household livelihoods, including relationship to markets;

iii) The intensity of production activities.

These criteria were applied to each of the six main regions of the developing world. The exercise resulted in the identification of 72 farming systems with an average agricultural population of about 40m inhabitants. Based on these criteria, eight broad categories of farming system have been distinguished.

- Irrigated farming systems, embracing a broad range of food and cash crop production;
- Wetland rice based farming systems, dependent upon seasonal rains supplemented by irrigation;
- Rainfed farming systems in humid areas, characterized by specific dominant crops or mixed crop-livestock systems;
- Rainfed farming systems in steep and highland areas, which are often mixed crop-livestock systems;
- Rainfed farming systems in dry or cold low potential areas, with mixed crop-livestock and pastoral systems merging into systems with very low current productivity or potential because of extreme aridity or cold;
- Dualistic (mixed large commercial and small holders) farming systems, across a variety of ecologies and with diverse production patterns;

- Coastal artisanal fishing systems, which often incorporate mixed farming elements; and
- Urban based farming systems, typically focused on horticultural and livestock production.

Except for the dualistic systems, the systems within each category are dominated by smallholder agriculture. The names chosen for individual farming systems reflect the eight categories outlined above. They also reflect key distinguishing attributes, notably: (i) water resource availability, e.g. irrigated, rainfed, moist, dry; (ii) climate, e.g. tropical, temperate, cold; (iii) landscape relief/altitude, e.g. highland, lowland; (iv) farm size, e.g. large scale; (v) production intensity, e.g. intensive, extensive, sparse; (vi) dominant livelihood source, e.g. root crop, maize, tree crop, artisanal fishing, pastoral; (vii) dual crop livelihoods, e.g. cereal-root, rice-wheat (note that crop-livestock integration is denoted by the term mixed); and (viii) location, e.g. forest based, coastal, urban based.

Of the 72 identified farming systems, from three to five systems were selected within each region for in depth analysis. Although the selection includes some farming systems with only limited opportunities for agriculturally based growth, a majority possess the potential for achieving significant hunger and poverty reduction if appropriate support is made available. Factors determining a system's apparent growth potential include: (i) suitable resource endowments, including underlying agro-climatic and soil conditions, a relatively high ratio of land and other resources (water, forest) to human population, and a currently low intensity of exploitation; (ii) favourable access to infrastructure and services, including markets; and (iii) the identification of broader development constraints whose removal is considered to be feasible. In broad terms, five main farm household strategies were defined that could contribute to improved farm household livelihoods and escape from poverty. These strategic options are not mutually exclusive, even at the individual household level; any particular household will often pursue a mixed set of strategies. The options can be summarized as:

- intensification of existing production patterns;
- diversification of agricultural activities;
- expanded operated farm or herd size;
- increased off-farm income, both agricultural and non-agricultural; and
- complete exit from the agricultural sector within a particular farming system.

Intensification is defined, for the purpose of this discussion, as increased physical or financial productivity of existing patterns of production; including food and cash crops, livestock and other productive activities. Diversification is defined as changes to existing farm enterprise patterns in order to increase farm income, or to reduce income variability. Diversification will often take the form of completely new enterprises, but may also simply involve the expansion of existing, high value, enterprises, and will be driven by market opportunities. The addition or expansion of enterprises refers not only to production, but also to on-farm processing and other farm-based, income generating activity.

Some households escape poverty by expanding farm size – in this context size refers to managed rather than to owned resources. Beneficiaries of land reform are the most obvious examples of this source of poverty reduction. Increased farm size may also arise through incursion into previously nonagricultural areas, such as forest – often termed expansion of the agricultural frontier. Although this option is not available within many systems, it is of particular relevance in parts of Latin America and sub-Saharan Africa. Increasingly, however, such 'new' lands are marginal for agricultural purposes, and may not offer sustainable pathways to poverty reduction. Off-farm income represents an important source of livelihood for many poor farmers. Seasonal migration has been one traditional household strategy for escaping poverty and remittances are often invested in land or livestock purchases. In locations where there is a vigorous non-farm economy, many poor households augment their incomes with part-time or full-time off-farm employment by some household members. Where few opportunities exist for improved rural livelihoods, farm households may abandon their land altogether, and move to other farming systems, or into non-farming occupations in rural or urban locations. This means of escaping agricultural poverty is referred to in the following chapters as exit from agriculture.

Aspects of the evolution of farming systems

In order to present the analysis of farming systems and their future development within a framework that is broadly comparable between systems and across different regions, key biophysical and socioeconomic determinants of system evolution have been grouped into five categories:

- Natural resources and climate;
- Science and technology;
- Trade liberalization and market development;
- Policies, institutions and public goods; and
- Information and human capital.

South Asia

Characteristics of the region

South Asia, as defined in this book, comprises eight countries including Afghanistan1. Agriculture accounts for a significant part of GDP throughout the region, and has grown at a remarkable overall rate during the past 30 years as a consequence of the Green Revolution. Nevertheless, the region has a greater number of undernourished and poor than any other developing region, and more than two-thirds of these reside in rural areas.

The South Asia region contains a population of 1344 million people, more than one quarter of the population of the developing world. Of these, 970 million (72 percent) live in rural areas. Approximately 150 million households, with 751 million people, can be classed as agricultural3. The combination of high population and limited land area (514 million ha), means that the rural population density in South Asia – at 1.89 persons per ha – is higher than in any other developing region. Moreover, the large proportion of inhospitable terrain has led to the concentration of most of the population on less than half of this land area, resulting in severe pressure on natural resources in many places.

The long history of human settlement has resulted in the utilisation of a wide diversity of natural resources for agriculture. In agro-ecological terms 4, 20 percent of the region's land consists of steeply sloping hills and mountains containing only five percent of the total population. Nineteen percent is densely populated, humid or moist sub-humid lowland containing the bulk (43 percent) of the region's people; while 29 percent is dry sub-humid and still heavily populated, as it contains 33 percent of the population. The remaining 32 percent is semiarid and arid lowland supporting only 19 percent of the region's inhabitants. Hill and mountain areas are found in all the countries, but predominate along the southern slopes of the Himalayan range across India, Bhutan, Nepal, Pakistan and Afghanistan. These hill areas have suffered from particularly extensive deforestation and soil erosion.

The humid and moist sub humid agro-ecological zones, which benefit from seasonal monsoon rains and more than 180 growing days per annum, are located in Bangladesh and around the northeastern, eastern and southern fringes of India, and cover the centre, west and south of Sri Lanka. With large areas of alluvial soils and a high proportion of the land under intensive rice cultivation, these areas support a particularly dense population. The dry sub-humid areas, characterized by 120 to 179 growing days each year, cover most of the Deccan Plateau in Central India. The northwest of India, most of Pakistan and Afghanistan are semiarid or arid with less than 120 growing days, low population density and large areas of desert. Throughout the region, there are about 74 million ha of forest (14 percent of total land area), 49 million ha of grazing land and about 213 million ha of cultivated land and permanent crops – equivalent to less than 0.16 ha of agricultural land per capita. Freshwater resources are relatively scarce.

Of the eight countries in the region, only the Maldives and Sri Lanka have achieved middle income status. Average per capita income is low: with a GDP of US$440 per capita. Official development assistance in 1998 amounted to only US$4 per capita (cf. US$21 per capita in Sub-Saharan Africa) and represented only 0.9 percent of regional GNP. Historically, the agriculture sector has generated the surpluses that have supported the growth and development of other sectors of the economy. This process is most advanced in India and Pakistan, where GADP comprises 27 percent7 and 24.6 percent8 respectively of national GDP. The value added from agriculture in 1999 was 28 percent of regional GDP9. The sector employs 59 percent10 of the labour force and generates 16 percent of the value of total exports11.

Major farming systems in south asia

For the purposes of this analysis, eleven broad farming systems have been identified. The geographical distribution of nine of the farming systems is indicated in the accompanying Map. The Urban Based and Tree Crop Farming Systems are not mapped. The main characteristics of the major farming systems, including the land area and agricultural population as a proportion of the regional total, principal livelihoods and prevalence of poverty, are shown in Table. A brief description of each farming system appears in the following paragraphs, and four are analysed in greater depth in subsequent sections.

Rice farming system

This farming system is dominated by intensive wetland rice cultivation 12 by farmers and sharecroppers in fragmented fields with or without irrigation. Of the total system area of 36 million ha, an estimated 22 million ha – or more than 60 percent – is under cultivation. Some 10 million ha, or 43 percent of the cultivated area, is irrigated. Of the total system population of 263 million inhabitants, 130 million are classified as agricultural (17 percent of the regional total). The system is concentrated in Bangladesh and West Bengal, but smaller areas are found in Tamil Nadu and Kerala States of India, and Southern Sri Lanka. The system contains 50 million bovines, used for draft Power, milk and manure, and considerable number of small ruminants. Poor farmers operate extremely small areas, and rely on off-farm income for survival. Poverty is extensive and also quite severe.

Coastal artisanal fishing farming system

In a narrow band along the major part of the coast of Bangladesh and India, and around the Maldives, households supplement artisanal (inshore) fishing with food production – often rice and such cash enterprises as coconuts, livestock and vegetables. The main livelihood is threatened by over-exploitation of the common resource, both locally and by larger well-equipped fishing boats. Total land area is estimated at five million ha with nearly half under cultivation. Coastal land resources are also under pressure from the high population density along the coastline, and from the expansion of modern and capital intensive aquaculture enterprises. One third of the cultivated area, or 0.8 million ha, is under irrigation. Of the total system population of 45 million, about 18 million are classified as agricultural. Off-farm income constitutes a significant source of livelihood, especially for poor households. The management of the system is complex from many points of view – the complexity associated with lying on the interface between marine and terrestrial ecosystems is aggravated by the complexity of numerous stakeholders with conflicting objectives. Poverty across the system ranges from moderate to extensive.

Rice-wheat system

Characterized by a summer paddy crop followed by an irrigated winter wheat crop (and sometimes also a short spring vegetable crop), the Rice-Wheat Farming System forms a broad swath across Northern Pakistan and India, from the Indus irrigation area in Sindh and Punjab, across the Indo-Gangetic plain to the northeast of Bangladesh. Total system area is 97 million ha with an estimated 62 million ha – more than 60 percent of the land of the system – under cultivation. An estimated 48 million ha, or 78 percent of the cultivated area, is irrigated. The system has a significant level of crop-livestock integration, with an estimated 119 million bovines which produce draft power and milk, as well as manure for composting. Around 73 million small ruminants are kept, principally for meat. Of the total system population of 484 million people, 254 million are classified as agricultural. The Rice and Rice-Wheat Farming Systems together contain 40 percent of the cultivated land in the region and produce the bulk of the marketed food grains that feed the cities and urban areas of South Asia.

Highland mixed farming system

This farming system, generally intermediate between the rice-wheat plains of the lowlands and the sparsely populated high mountain areas above, extends across the entire length of the Himalayan range, from Afghanistan to the extreme northeast of India, as well as in isolated areas of Kerala and Central Sri Lanka. Major products include cereals, legumes, tubers, vegetables, fodder, fodder trees, orchards and livestock. Total system area is 65 million ha with an estimated 19 million ha – about 29 percent – under cultivation. While most cultivated land is rainfed, an estimated 2.6 million ha, or 14 percent, is irrigated. There are about 45 million bovines and 66 million small ruminants. Of the total human population of 82 million, nearly 53 million are classified as agricultural. The prevalence of poverty, which is aggravated by remoteness and the lack of social services, is rated between moderate and extensive.

Rainfed mixed farming system

This predominantly rainfed cropping and livestock farming system occupies the largest area within the sub-continent and, with the exception of a small area in Northern Sri Lanka, is confined entirely to India. Total system area is 147 million ha with an estimated 87 million ha (59 percent) under cultivation. Rice and some wheat are grown, as well as pearl millet and sorghum, a wide variety of pulses and oilseeds, sugarcane, and vegetables and fruit. An estimated 14 million ha, or 16 percent of the cultivated area, is irrigated. There are an estimated 126 million bovines and 64 million small ruminants, which are partially integrated with cropping. Of the total system population of 371 million, 226 million are classified as agricultural. In many instances, relatively small areas are irrigated from reservoirs and in recent decades, tube-wells have contributed to an elevated level and stability of cereal production. Vulnerability stems from the substantial climatic and economic variability. Poverty is extensive and its severity increases markedly after droughts.

Dry rainfed farming system

Located in a 'rain shadow' surrounded by the Rainfed Mixed Farming System in the Western Deccan, this farming system has a higher proportion of irrigation than the moister surrounding areas, allowing it to support a similar range of irrigated and rainfed crops despite the drier climate. Total system area is 18 million ha with an estimated 10 million ha – about 53 percent – under cultivation. An estimated 3.5 million ha, or 36 percent of the cultivated area, is irrigated – and this irrigation is a central determinant of the farming system. Of the total system population of 45 million, nearly 30 million are classified as agricultural. Because of the prevalence of irrigation, vulnerability is somewhat lower than in the neighbouring Rainfed Farming System, and thus the level of poverty is moderate.

Pastoral farming system

Across the semiarid and arid zones, from Rajasthan in India through Pakistan and Afghanistan, transhumant pastoralists keep mixed herds of livestock. The system includes scattered pockets of irrigation which mitigate the extreme seasonal vulnerability of pastoralists. Total system area covers 55 million ha, and it supports an estimated 12 million cattle and 30 million small ruminants, as well as a significant number of camels. There are scattered areas of cultivation amounting to an estimated 6.8 million ha, of which nearly two thirds (4.6 million ha) is irrigated and sown to rice, wheat and other food and fodder crops. Off-farm income is an important source of livelihood. Of the total system population of 27 million, around 21 million are classified as pastoral or agricultural. In aggregate terms, this farming system is not of great importance, supporting only three percent of the human population and less than 10 percent of the livestock of the region. The level of poverty is moderate to extensive, and is periodically accentuated by droughts.

Sparse (arid) farming system

The land area of the system is estimated at 57 million ha, supporting an estimated 16 million bovines and 29 million small ruminants. About 1.7 million ha is cultivated, practically all under irrigation. There are some scattered irrigation settlements in the arid areas; in most cases used by pastoralists to supplement their livelihoods. The rest of these areas are utilised for opportunistic grazing where water is available for livestock. The human population is 23 million, of which 9.6 million are classified as pastoral or agricultural. There is a gradual transition from the Pastoral System to this system, which has moderate to extensive poverty that is often severe after droughts.

Sparse (mountain) farming system

This system lies at altitudes above 3000 metres along the mid level and upper slopes of the Himalayan Range and occupies an estimated area of 34 million ha with a population of 3 million people, of whom 2.8 million are classified as agricultural. A number of small settlements depend on potatoes and buckwheat, plus cattle and yak herds. Cultivated area is 1.9 million ha, or only five percent of total area, and only around 10 percent is irrigated. There are an estimated 10 million cattle and yaks, and nine million sheep and goats. During the summer, herders graze cattle and yak on the higher slopes. Generally, household incomes are supplemented by seasonal migration and in some cases by trade, mountaineering and tourism. Poverty tends to be moderate overall, although more prevalent in remote areas.

Tree crop farming system

This scattered farming system comprises plantation companies and smallholders producing substantial areas of tea, rubber, coconuts and other tree crops. It is estimated that the system covers three million ha of land, with some 1.2 million ha of annual and permanent cropland. Concentrations of this system are found in the lowlands of Sri Lanka (especially coconuts), Kerala in India (including spices), and upland areas of India, Nepal, Bangladesh and Sri Lanka (tea estates). The estimated agricultural population is seven million. Poverty is moderate and largely confined to agricultural workers.

Urban based farming system

In most large towns and cities in the region the intensive production of perishable high-value commodities – such as milk and fresh vegetables – has expanded. These are generally commercial systems with high levels of external inputs and with effective links to the surrounding rural areas for stock feed and fodder. The system has an agricultural population of 11 million, and contains around 12 million head of bovines (cattle and buffaloes).

Table 3. Major farming systems in south asia

Farming Systems	Land Area (% of region)	Agric. Popn. (% of region)	Principal Livelihoods	Prevalence of Poverty
Rice	7	17	Wetland rice (both seasons), vegetables, legumes, off-farm activities	Extensive
Coastal Artisanal Fishing	1	2	Fishing, coconuts, rice, legumes, livestock	Moderate-extensive
Rice- Wheat	19	33	Irrigated Rice, wheat, vegetables, livestock including dairy, off-farm activities	Moderate-extensive
Highland Mixed	12	7	Cereals, livestock, horticulture, seasonal migration	Moderate-extensive
Rainfed Mixed	29	30	Cereals, legumes, fodder crops, livestock, off-farm activities	Extensive (Severity varies seasonally)
Dry Rainfed	4	4	Coarse cereals, irrigated cereals, legumes, off-farm activities	Moderate
Pastoral	11	3	Livestock, irrigated cropping, migration	Moderate-extensive (especially drought induced)

Farming Systems	Land Area (% of region)	Agric. Popn. (% of region)	Principal Livelihoods	Prevalence of Poverty
Sparse (Arid)	11	1	Livestock where seasonal moisture permits	Moderate-extensive (especially drought induced)
Sparse (Mountain)	7	0.4	Summer grazing of livestock	Moderate (especially in remote areas)
True Crop	Dispersed	1	Export or agro-industrial crops, cereals, wage labour	Moderate (mainly of agricultural workers)
Urban Based	<1	1	Horticulture, dairying, poultry, other activities	Moderate

Region-wide trends in South Asia

Population, hunger and poverty

The region's 1999 population of about 1344 million13 is expected to increase by approximately 1.4 percent per annum to 1650 million in 2015. Thereafter, population growth is expected to slow to about 1 percent per annum to reach 1920 million by 2030. The proportion of the total population living in cities (presently 28 percent14) has increased markedly over the last four decades and is expected to continue to expand, reaching 53 percent in 2030.

Natural resources and climate

The area of land under annual cultivation and permanent crops in the region is estimated at 213 million ha (49 percent of total land area) and is expected to show only a marginal increase by 2030. The overall scarcity of water resources in the region, and their geographic distribution, has shaped the development of South Asia's farming systems. The region's irrigated land area is forecast to grow slowly, from 85 million ha to 95 million (44 percent of cultivated land) in 2030.

Science and technology

Agricultural research in South Asia has been strengthened dramatically over the past 40 years through re-organisation of the National Agricultural Research Systems (NARS); with the establishment of central coordinating bodies, decentralisation into regional research centres, greatly enhanced manpower and increased investment. The NARS in the region have benefited greatly from the strong linkages and networks they have established with International Agricultural Research Centers (IARCs), such as IRRI, CIMMYT and ICRISAT, building on their participation in the development of green revolution technology. More recently, the many NARS have shifted their emphasis to meeting the post-green-revolution challenges of stagnant yields and resource management, by developing technologies for resource-poor farmers and farmers in sub-optimal crop environments.

Table 4. Trends in Crop Area, Yield and Output in South Asia, 1970-2000

Crop	Harvested Area 2000 (m ha)	Yield 2000 (t/ha)	Production 2000 (m tons)	Annual average change 1997- 2000 (%)		
				Area	Yield	Production
Rice	60	3.1	184	0.5	2.0	2.5
Wheat	39	2.5	98	1.4	2.8	4.3
Millet	13	0.8	10	-1.7	0.7	-1.0
Sorghum	11	0.9	10	-1.6	0.7	0.5
Maize	8	1.7	14	0.4	1.0	1.6
Pulses	27	0.6	15	0.3	0.2	0.5
Oil Crops	42	0.2	10	1.3	1.4	2.6
Vegetables	8	10.7	71	1.7	1.2	3.0
Fruits	3	1.3	40	3.0	1.2	4.3

Key region-wide trends

The region's 1999 population of about 1344m is expected to reach 1920m by 2030, and the proportion living in cities will rise to 53 percent. The proportion in dollar poverty is projected to decline from 40 percent to approximately 20 percent. Area cultivated is expected to show only a marginal increase while irrigated land area will continue to grow slowly. Rice yields have increased by an average of almost 2 percent per annum over the last 30 years. Wheat production increased by more than 250 percent to almost 100m tons in 2000 and the growth rate of both crops is expected to be maintained in the period to 2030. Use of inorganic fertilizers has expanded rapidly in recent decades; from 3 kg of plant nutrients per ha in 1970 to 79 kg/ha in the mid-1990s, and is expected to continue to increase, albeit more slowly. With higher incomes, meat consumption (particularly poultry meat and eggs, sheep and goat meat) and demand for dairy products are expected to continue their significant expansion. However, the large ruminant population is likely to stabilize, or even decline, as tractors replace both draught buffalo and oxen.

Strategic priorities for South Asia

Given their importance for poverty reduction across many different systems, strong support will be needed both for small farm diversification and for growth in employment opportunities in the off-farm rural economy. Measures that assist farm households to leave agriculture will be an important secondary priority, and would need to include improved rural education and vocational skills training. There is also some potential for poverty reduction by means of intensification of existing production patterns, largely through improved water management and adoption of improved technologies. Because of the pressure on land, there is less opportunity than elsewhere for poverty reduction through the expansion of the farms of poor small farmers. Thus, sustainable utilization of the land and water resource base represents a key strategic priority.

Decentralization and the strengthened performance of local institutions will be essential for the development of most farming systems. Investments in roads and educational services should be an essential ingredient of any strategy for accelerating agricultural production and rural development. Priority should also be given to the integration of better on-farm nutrient management (INM) – combining inorganic and organic nutrient sources – and to economic incentives for balanced fertilizer use. Conservation agriculture should be introduced; including the greater integration of livestock and trees into the system.

Significant improvement in water management will only be possible if functioning markets for water are established and realistic water charges are introduced. A double benefit, to growth and to poverty reduction, could result from an overhaul of obsolete land tenure policies and regulations. Considerable investment is needed in local commodity markets and price information systems, especially in the more remote farming systems, as well as further development of rural financial services including micro-finance and linkages to mainstream banking. A high priority for investment in the coming 30 years would be empowering small farmers to access improved information on markets, services and technologies. Increases of human capital are required in order to underpin diversification towards high value skill-intensive enterprises as well as the development of small-scale local rural industry.

Agricultural development will remain an important component of poverty reduction programmes for the foreseeable future in South Asia. There are some major resource degradation challenges, as well as linkages to the off-farm rural economy, to be taken into account. The main source of reduction of hunger and poverty would be diversification to high value enterprises, including local processing. Increased off-farm income and intensification of existing production patterns are next in importance, followed by exit from agriculture. Increased farm size is expected to be of lesser importance. Four broad strategic initiatives are proposed

Improved water resource management: Improved water management is essential to support the intensification and diversification of production and to reduce resource depletion, for both surface and underground water schemes. Components include: technology; conjunctive use; water charges and other regulatory measures; strengthened water users' associations; and watershed protection.

Strengthened resource user groups: Strengthening resource user groups is one way to redress the extensive land and water degradation in plains and hills, and protect watershed resources. Components include: resource management groups for watershed management in hill and mountain areas; range management groups in pastoral areas; and policies to encourage effective common property resource management.

Improved rural infrastructure: Returns to transport and health investments are high and beneficial to the poor, especially in low potential and highland areas in the region. Components include: roads; drinking water; schools; health facilities; and effective models for private sector participation.

Re-oriented agricultural services: The re-orientation of agricultural research, education, information and extension systems to involve farmers fully will underpin the drives for intensification and enterprise diversification and promote sustainable resource management. Components include: models for joint public-private service provision; pluralistic advisory services; Internet based delivery of service, market and technical information to small farmers; and the incorporation in higher education learning systems of interdisciplinary learning and approaches.

Sub-Saharan Africa

The region and its farming systems

The region7 contains 626m people of whom 61 percent (384m) are directly involved in agriculture. Total land area is 2 455m ha, of which 173m ha are under cultivation (annual and perennial crops) – about one quarter of the potential area. Arid and semiarid agro-ecological zones encompass 43 percent of the land area. In West Africa, 70 percent of the total population lives in the moist sub humid and humid zones, whereas in East and Southern Africa only about half the population occupies these areas.

Despite an abundance of natural resources, the regional GDP per capita was lower at the end of the 1990s than in 1970. Nineteen of the 25 poorest countries in the world are found in sub-Saharan Africa and income inequality is high. In East and Southern Africa, it is estimated that rural poverty accounts for as much as 90 percent of total poverty. During the past 30 years the number of undernourished people in the region has increased substantially, to an estimated 180m people in 1995-1997.

Fifteen farming systems have been identified and are summarized in Table. Given the number of farm households that may be encompassed by a single farming system, it is inevitable that significant heterogeneity exists within the broader systems and important subsystems can be identified in many cases. The five most important of these systems from the perspective of population, poverty and potential for growth are briefly described below.

Irrigated farming system: This comprises large-scale irrigation schemes covering 35m ha with an agricultural population of 7m. Irrigated production is supplemented by rainfed cropping or animal husbandry. Water control may be full or partial. Holdings vary in size from 22 ha per household in the Gezira scheme, to less than 1.0 ha. Crop failure is generally not a problem, but livelihoods are vulnerable to water shortages, scheme breakdowns and deteriorating input/output price ratios. Many schemes are currently in crisis, but if institutional problems can be solved future agricultural growth potential is good. The incidence of poverty is lower than in other farming systems and absolute numbers of poor are small.

Tree crop farming system: This is found largely in the humid zone of West and Central Africa and occupies 73m ha with an agricultural population of 25m. Cultivated area is 10m ha, of which only 0.1m are irrigated. It is dominated by the production of industrial tree crops; notably cocoa, coffee, oil palm and rubber. Food crops are inter-planted between tree crops and are grown mainly for subsistence; few cattle are raised. There are also commercial tree crop estates (particularly for oil palm and rubber) in these areas, providing services to smallholder tree crop farmers through nucleus estate and out grower schemes. The incidence of poverty is limited to moderate, and tends to be concentrated among very small farmers and agricultural workers.

Cereal-root crop mixed farming system: This extends through the dry sub humid zone of West Africa, and parts of Central and Southern Africa. Total area is 312m ha with an agricultural population of 59m. Cultivated area is 31m ha of which only 0.4m are irrigated. Cattle are numerous – some 42m head. Although maize, sorghum and millet are widespread, root crops such as yams and cassava are more important. Intercropping is common, and a wide range of crops is grown and marketed. The main source of vulnerability is drought. Poverty incidence is limited and agricultural growth prospects are excellent. This system could become the breadbasket of Africa and an important source of export earnings.

Maize mixed farming system: This is the most important food production system in East and Southern Africa, extending across plateau and highland areas at altitudes between 800m and 1500m. Total area is 246m ha with an agricultural population of 60m. Cultivated area is 32m ha of which only 0.4m are irrigated. The main staple is maize and the main cash sources are migrant remittances, cattle, small ruminants, tobacco, coffee and cotton, plus the sale of food crops such as maize and pulses. About 36m cattle are kept. The system is currently in crisis as input use has fallen sharply due to shortage of seed, fertilizer and agro-chemicals, plus the high price of fertilizer relative to the maize price. The main sources of vulnerability are drought and market volatility. There is a moderate incidence of chronic poverty. In spite of current problems, long-term agricultural growth prospects are relatively good and the potential for reduction of poverty is high.

Agro-pastoral millet/sorghum farming system: this occupies the semiarid zone of West Africa and substantial areas of East and Southern Africa. Total area is 198m ha with an agricultural population of 33m. Cultivated area is 22m ha and pressure is very high on the limited amount of cultivated land available. Crops and livestock are of similar importance.

Rainfed sorghum and pearl millet are the main sources of food, while sesame and pulses are sometimes sold. The system contains nearly 25m head of cattle as well as sheep and goats. The main source of vulnerability is drought, while poverty is extensive and often severe. The potential for poverty reduction is only moderate.

Key region-wide trends

HIV/AIDS has already depressed population growth rates, but total numbers are still expected to increase by 78 percent in the coming three decades, although rural population will rise by only 30 percent due to rapid urbanization. Total annual and permanent cropped area is expected to expand slowly in the years up to 2030, and with an average rise in crop yields of 60 percent and a slow rise in irrigated area and fertilizer use, production of all crops is forecast to more than double. Livestock production is projected to grow at a moderate rate due to expansion of urban consumer demand for meat, milk and eggs. Most agricultural production will continue to come from smallholder dominated rainfed farming.

Table 5. Major farming systems of sub-Saharan Africa

Farming Systems	Land Area (% of region)	Agric. Popn. (% of region)	Principal Livelihoods
Irrigated	1	2	Rice, Cotton, vegetables, rainfed crops, cattle, poultry
Tree Crop	3	6	Cocoa, coffee, oil palm, rubber, yams, maize, off-farm work
Forest based	11	7	Cassava,maize, beans, cocoyams
Rice- Tree Crop	1	2	Rice, banana, coffee, maize, cassava, legumes, livestock, off-farm work
Highland Perennial	1	8	Banana, plantain, enset, coffee, cassava, sweet potato, beans, cereals, livestock, poultry, off-farm work
Highland Temperate Mixed	2	7	Wheat barley, tef, peas, lentils, broadbeans, rape, potatoes, sheep, goats, livestock, poultry, off-farm work
Root Crop	11	11	Yams, cassava, legumes, off-farm work
Cereal-Root Crop Mixed	13	15	Maize, sorghum, millet, cassava, yams, legumes, cattle
Maize Mixed	10	15	Maize, tobacco, cotton, cattle, goats, poultry, off-farm work
Large Commercial and Smallholder	5	4	Maize, pulses, sunflower, cattle, sheep, goats, remittances
Agro-Pastoral Millet/Sorghum	8	8	Sorghum, pearl millet, pulses. sesame, cattle, sheep, goats, poultry, off-farm work

Farming Systems	Land Area (% of region)	Agric. Popn. (% of region)	Principal Livelihoods
Pastoral	14	7	Cattle, camels, sheep, goats, remittances
Sparse (Arid)	17	1	Irrigated maize, vegetables, date palms, cattle, off-farm work
Coastal Artisanal Fishing	2	3	Marine fish, coconuts, cashew, banana, yams, fruit, goats, poultry, off-farm work
Urban Based	<1	3	Fruit, vegetables, dairy, cattle, goats, poultry, off-farm work

Source: FAO data and expert knowledge.

Strategic priorities for Sub-Saharan Africa

Despite the fact that sub-Saharan Africa is relatively well endowed with natural resources, the incidence of hunger and poverty is greater than in other developing regions, while the population growth rate is higher and the number of poor is increasing at an alarming rate. Nevertheless, the policy, economic and institutional environment still does not create the necessary incentives for agricultural production. There is a continuing urban bias in development programmes and the supply of rural public goods is low. Efforts must be directed to support the intensification of productivity on the farms of poor households, as well as the diversification of production towards high return activities, especially in the high potential areas where a majority of the poor are found. The development of alternative livelihoods – both local off-farm employment and exit from agriculture – will be an important component of poverty reduction programmes, especially in the low potential areas.

Substantial benefits would be derived from a renewed focus on improved agricultural sector policies. Two major priority areas stand out in this respect: (i) resource user rights and (ii) long-term investments in public goods. Examples of the latter include: good land husbandry; sustainable natural resource management; soil and water conservation; environmental protection; maintenance of biodiversity; tsetse eradication; and, carbon sequestration. Farming systems with high growth potential are strongly constrained by a lack of services, including transportation and education. The challenge is to provide such public goods in a sustainable fashion, by ensuring that local authorities and communities contribute to their maintenance. It is necessary to develop productive partnerships between public, private sector and civil society, notably farmers' organizations.

In general terms, not only should non-traditional exports be promoted but there is also a need for a general focus on higher value products. Partial solutions include: diversification into non-traditional export crops; upgrading of existing export products to obtain the highest possible price (rehabilitation, improved processing); and a search for niche markets such as biologically produced items and African ethnic foods.

The abundance of natural resources in the region provides the basis for pro-poor agricultural development if the appropriate incentives are created. The analysis of major farming systems indicates the relative importance of household strategies to escape poverty – in order of importance: diversification; intensification; increase in farm size; exit from agriculture; and increase in off-farm income. In order to halve hunger and poverty by the year 2015, massive efforts are required to stimulate broad-based, inclusive growth, which ultimately depends on the initiative and effort of individual farm families within each farming system. Although it is impossible, based on the foregoing regional analysis, to prescribe specific national actions, the overall challenge of reducing hunger and poverty in the region demands five strategic, inter-linked, initiatives.

***Sustainable resource management**:* Sustainable resource management must address widespread land degradation, declining soil fertility and low crop yields; it should result in soil recapitalization and improved resource productivity. Components include: farmer centered agricultural knowledge and information systems to document and share successes; resource enhancements such as small-scale irrigation and water harvesting; participatory applied research focused on integrated technologies blending indigenous and scientists' knowledge, related to conservation agriculture, agro forestry, IPM and crop-livestock integration; and strengthening resource user groups.

Improved resource access: Access to agricultural resources by poor farmers is intended to create a viable resource base for small family farms. Components include: market-based land reform; adjustment of land legislation; strengthened public land administration; and functional community land tenure.

Increased small farm competitiveness: Increasing competitiveness of small and poor farmers will build capacity to exploit market opportunities.

Components include: improved production technology; diversification; processing; upgrading product quality; linking production to niche markets; and strengthening support services, including market institutions based on public-private partnerships.

Reduced household vulnerability: Household risk management will reduce the vulnerability of farm households to natural and economic shocks, both of which are prevalent in African agriculture. Components include: drought-resistant and early varieties and hardy breeds; improved production practices for moisture retention; insurance mechanisms; and strengthening traditional and other risk spreading mechanisms.

Responding to HIV/AIDS: Immediate action is required to halt the spread and impact of HIV/AIDS. Components include: information campaigns; a cheap supply of condoms; affordable treatment; land tenure reform to prevent widows losing access to, and control over, land and household property when their husbands die; agricultural training for AIDS orphans; and, safety nets to reinforce the efforts of rural communities to support AIDS orphans.

Middle East and North Africa

The region and its farming systems

The region8 comprises low and middle-income countries stretching from Iran to Morocco (see Map). The region supports a population of 296m people, over 120m of whom live in rural areas. Of these, about 84m are dependent on agriculture – including fishing and livestock. The region covers an area of 1100m ha and includes a diversity of environments. However, arid and semiarid areas with low and variable rainfall predominate. Moderately humid zones account for less than 10 percent of the land area but nearly half of the agricultural population, while the drier areas account for nearly 90 percent of the land area but less than 30 percent of the population. Rainfed crops are grown during the wetter winter period, while irrigated areas are cultivated year round. The main rainfed crops are wheat, barley, legumes, olives, grapes, fruit and vegetables. Livestock, mainly sheep and goats, are an important feature of many farming systems. A high proportion of poor households consists of farmers or pastoralists who depend on agriculture as a primary food and livelihood source.

Eight major farming systems have been identified and broadly delimited, based on a range of criteria and are listed in Table. The most important of these systems from the perspective of population, poverty and potential for growth are briefly described below.

Irrigated farming system: The system contains both large and small-scale irrigation schemes. The large-scale subsystem contains a total population of 80m and an agricultural population of 16m. It encompasses 8.1m ha of cultivated land that is almost totally irrigated and schemes are found across all zones. They include high-value cash and export cropping and intensive vegetable and fruit cropping. The small-scale irrigation subsystem also occurs widely across the region and although not as important in terms of population, it is a significant element in the survival of many people in arid and remote mountain areas. Owner-occupiers or tenants typically farm very small units – from 0.02 to 1 ha – often within an area of larger, rainfed systems. Major crops are mixed cereals, fodder and vegetables. The prevalence of poverty within both subsystems is moderate.

High land mixed farming system: This system is the most important in the region in terms of population – with 27m engaged in agriculture – but contains only 7 percent of the land area. Out of a total area of 74m ha, cultivated area covers 22m ha, with nearly 5m ha irrigated. There are two subsystems; one dominated by rainfed cereal and legumes plus tree crops (fruits and olives) on terraces, while the second is based on livestock (mostly sheep) on communally managed lands. Poverty is extensive, as markets are often distant, infrastructure is poorly developed and the degradation of natural resources is a serious problem.

Rainfed mixed farming system: The system has an agricultural population of 16m, but occupies only 2 percent of the regional land area, resulting in high population densities. Cultivated area is 14m ha, including tree crops and vines, with 8m cattle. Supplementary winter irrigation is now used on 0.6m ha of wheat and on summer cash crops. More humid areas are characterized by tree crops (olives and fruit), melons and grapes. There is some dry-season grazing of sheep migrating from the steppe areas. Poverty is moderate, but would be higher without extensive off-farm income from seasonal labour migration.

***Dryland mixed farming system**:* The system is found in dry sub-humid areas and contains an agricultural population of 13m people with 17m ha of cultivated land. Population density tends to be lower than in the other main cultivated systems and average farm sizes are larger. The main rainfed cereals are barley and wheat, grown in a rotation involving an annual or two-year fallow. The risk of drought is high and considerable food insecurity exists. Livestock, including 6m cattle and a greater number of small ruminants, interact strongly with the cropping and fodder system. Poverty is extensive among small farmers.

Key region-wide trends

The most significant trend over the past 30 years has been accelerating urbanization and the consequent growth of cities. This trend is likely to continue, resulting in rapidly rising demand for water and food – particularly cereals and livestock products. During the period 2000-2030, the population of the region is projected to almost double from its present 296m. This could have a considerable negative impact in areas with fragile or vulnerable soils and sloping land, and will certainly be of importance for water resources everywhere. Although there is limited scope for further expansion, cultivated land use will increase to 82 percent of total potential. However, the newly cultivated land will often be seriously constrained by climate, slope or poor soils. During 2000-2030, the total irrigated area is forecast to grow by 20 percent. This will bring total irrigated area to a level equal to 77 percent of all land with irrigation potential. Overall irrigation water requirements are expected to grow by 14 percent and efficiency of water use is estimated to reach 65 percent. The overall total of 6 percent projected growth in calorie consumption is low, but the region will still achieve an average daily intake of 3170 kcal by 2030; comfortably exceeding the developing world average of 3020 kcal.

Table 6. Major Farming Systems of Middle East and North Africa

Farming Systems	Land Area (% of region)	Agric. Popn. (% of region)	Principal Livelihoods
Irrigated	2	17	Fruits, vegetables, cash crops
Highland Mixed	7	30	Cereals, legumes, sheep, off-farm work
Rainfed Mixed	2	18	Tree crops, cereals, legumes, off-farm work
Dry land Mixed	4	14	Cereals, sheep, off-farm work
Pastoral	23	9	Sheep, goats, barley, off-farm work
Sparse (Arid)	62	5	Camels, sheep, off-farm work
Coastal Artis-anal Fishing	1	1	Fishing, off-farm work
Urban Based	<1	6	Horticulture, poultry, off-farm work

Source: FAO data and expert knowledge.

Strategic Priorities for Middle East and North Africa

The priority roles of the State are to develop vital infrastructure (roads, water supplies, services, power systems) and to regulate resource use and foster markets for increasingly scarce resources – notably water. Greater devolution and sub regional disbursement of resources appear to be essential, together with greater participation in the development of collective stakeholder responsibility for management and protection of land, water and grazing resources. This requires the strengthening of local institutions and community empowerment, plus the development of more constructive partnerships between the private sector, major donors and the State. Legislation and regulation is needed to control the grazing pressure on dry lands and uplands. These actions should be linked to: the elimination of import subsidies, particularly for grains used for intensive livestock production; the establishment of producer marketing groups; and the formation of action research groups.

Irrigated systems, unlike many others, offer the possibility for greater diversification, intercropping and tree or crop intensification. A further area for investment is the diversification and shift to water saving cropping patterns. This requires rapid development and access by farmers to micro-water distribution systems that are currently used only by a relatively small group of commercial farmers. New systems of cropping sequences, intercropping and in-season management need to be explored by proactive farmer-researcher groups. The introduction of conservation agriculture techniques, equipment and strategies that make better use of labour, soil and water resources are also of the highest importance in the region.

Despite the oil-based wealth of some countries of the region, agricultural production and water resources are still vital to the livelihoods of many farming families. Prospects for reducing agricultural poverty and adhering to the current international goals in this respect are fairly good. For the region as a whole, exit from agriculture is the most important of the available household strategies for reducing poverty and food insecurity, followed by increased off-farm income. Among on-farm household improvement strategies, diversification and intensification are of equal importance, following closely behind off-farm income in the overall ranking. Increased farm size appears to be of minor importance overall.

Two major groups continue to be excluded from most development initiatives: poorer farmers in dryland areas and pastoralists. There are many threats to the stability and sustainability of natural resource based systems and additional pressure has resulted from weak or inappropriate food policies, which have supported low urban prices at the expense of poorer farmers and livestock herders. Nonetheless, lessons have been learned and there has been a gradual acceptance of the need to re-orientate development towards the elimination of poverty, based upon sustainable resource use. Five broad strategic initiatives are proposed:

***Sustainable resource management:* Natural resources need to be conserved, through improved watershed management in hill and mountain areas, soil conservation in sloping lands and improved range management in pastoral areas. Components include: strengthening local resource-user groups; better management practices; and improved long-term policies.**

Improved irrigation management: Increased efficiency in irrigation water management is essential to support the intensification and diversification of production and to reduce resource depletion. Components include: schemes based on both surface and underground water technology; and adjustments to water charges and other regulatory measures.

Re-oriented agricultural services: The re-orientation of agricultural research systems to fully involve farmers will underpin intensification in the Irrigated and Rainfed Mixed Systems and enterprise diversification in all systems. Components include: extension services based on a variety of public and private service providers; and greater support for rural agribusinesses to create off-farm employment for farmers.

Revitalized agricultural education systems: New approaches to science and higher education learning systems are particularly important in the training of agriculturalists who will work in both the public and private sectors. Components include: the adoption of the significant advances in interdisciplinary learning and systemic thinking which have played such an important role in agricultural education elsewhere in the world.

Rationalized agricultural policies: Policies need to reorientate development towards the elimination of poverty based upon sustainable resource use. Components include: eliminating subsidies for the importation of cheap grains, as well as other forms of support for low urban prices at the expense of poorer farmers and pastoralists.

Eastern Europe And Central Asia

The region and its farming systems

The region encompasses 28 countries, most of which have experienced major economic reforms during the recent past. There are two sub regions with significant differences in the progress and outcome of these reforms: (i) Central and Southeastern Europe (CSEE); and (ii) the Commonwealth of Independent States (CIS). The first includes the Baltic States, Poland, Central and Southern European countries and Turkey and covers an area of 210m ha with a rural population of 67m, of whom 38m are active in agriculture. The most productive area lies in the moist sub humid agro ecological zone. Mountain and hilly areas with more than 30 percent slope are widespread in the southern part of the sub-region. The CIS includes all former Soviet Union countries except the Baltic States, and covers a total area of 2 180m ha with a population of 284m, of whom 33 percent are rural. Huge areas, covering more than half of the region, lie in the arid or dry sub humid north where permafrost and lack of moisture render them unsuitable for crop production, and where population density is less than three inhabitants/km2. The sub-region's most productive farming systems lie in the moist sub humid agro-ecological zone, in the west. The major part of the sub-region lies in the arid and semiarid zone and has only limited production potential, unless irrigated. Both sub-regions have experienced dramatic falls in output, a rise in inequality and an increase in the number of people in poverty. Altogether eleven major farming systems have been identified and are summarized in Table below.

Table 7. Major farming systems of eastern europe and central asia

Farming Systems	Land Area (% of region)	Agric. Popn. (% of region)	Principal Livelihoods
Irrigated	1	4	Cotton, rice, other cereals, tobacco, fruit, vegetables, off-farm
Mixed	4	18	Wheat, maize, oilcrops, barley, livestock
Forest based Livestock	3	5	Fodder, hay, cereals, industrial crops, potatoes
Horticulture Mixed	3	11	Wheat, maize, oilcrops, fruit, intensive vegetables, livestock, off-farm income
Large scale Cereal- Vegetable	4	16	Wheat, barley, maize, sunflower, sugarbeet, vegetables
Small scale Cereal- Livestock	1	4	Wheat, barley, sheep and goats
Extensive Cereal-Livestock	18	15	Wheat, hay, fodder, cattle, sheep
Pastoral	3	10	Sheep, cattle, cereals, fodder crops, potatoes
Sparse (Cold)	52	2	Rye, oats, reindeer, potatoes, pigs, forestry
Sparse (Arid)	6	8	Barley, sheep
Urban Based	<1	7	Vegetables, poultry, pigs

Source: FAO data and expert knowledge.

The three most important of these from the perspective of population, extent of poverty and potential for growth and poverty reduction are briefly described below.

Mixed farming system: This system has an area of 85m ha, lying within intermontane lowland plains in a moist sub humid zone and the cultivated area of 35m ha is largely dedicated to wheat, maize, oil crops and barley, combined with smaller areas of fruit and vegetables. Agricultural population is 16m. Livestock production is dominated by dairy and beef, plus pork. Associated hill and mountain areas are used for grazing and forestry. It is characterized by two dominant subsystems: small- to medium-scale private family farms and medium to large corporate or co-operative farms. Poverty is moderate and concentrated among the most vulnerable groups; such as ethnic minorities, unemployed and unskilled workers, and those farming in marginal areas.

Large-scale cereal-vegetable farming system: This system, typical of Ukraine, the Southwest part of the Russian Federation and the Republic of Moldova, covers 100m ha with 38m ha cultivated, principally in the moist sub humid agro-ecological zone. The agricultural population is 15m, and the main crops are wheat, barley, maize, sunflower, sugar beets and vegetables. Most of the farms are still large – ranging from 500 to 4000 ha – and the dominant ownership is co-operative or corporate. They generate little or no cash income and co-operative members or farm labourers depend on production from their household plot to sustain their families. Poverty is moderate to extensive.

Extensive cereal-livestock farming system: This system is found throughout the semiarid agroecological zone of the Russian Federation and Northern Kazakhstan, but also covers substantial areas in Southern Kazakhstan, Turkmenistan and Uzbekistan. It occupies a total of 425m ha, of which about 106m ha are cultivated, and has an agricultural population of 14m. This is the domain of the steppe, traditionally used by transhumant herders, until converted to cropping over the last few decades. The major outputs are wheat, hay and other fodder crops, combined with cattle and sheep. In the drier parts, with an annual rainfall of only 200 to 300 mm, the land is fallowed every two years. Ownership patterns are in transition, from collective and state farms to co-operative or corporate ownership, with an increasing number of smaller family farms. Poverty is increasing among old people, young families and former co-operative members, as well as in urban areas.

Key region-wide trends

Unlike other low and middle-income regions, total populations are stagnant at present, and agricultural populations are ageing in many countries. In part, this lack of population growth may reflect the steep decline in living standards experienced within the region since the collapse of the centrally planned economic system in the late 1980s. Per capita calorie consumption, which in the mid-1980s was higher than in the industrialized countries, had fallen by nearly 15 percent a decade later. Poverty levels have increased even faster than hunger – with the estimated number of people in poverty (as defined nationally) rising from 14m in 1987-1988 to 147m in 1993-1995.

Past trends indicate a decrease in cultivated land use during the 1990s, following decades of large-scale expansion of ploughed land to the detriment of marshes, forests and steppes – often in areas unsuitable for sustainable agriculture. It is likely that cropping in some of the more marginal areas will be abandoned. Cropping patterns have changed to accommodate an increased share of food crops at the expense of forage and industrial crops. Crop yields have fallen and one reason for decreased productivity has been lower fertilizer use. Yields are expected to increase in future, but only very slowly, catalyzed by farm recapitalization, availability of improved technologies, and increasing experience in crop management in a non-subsidized low external input setting. Market-led changes in cropping pattern are expected, with a trend away from staple cereals towards higher value crops. During the last

10 years, livestock production has also been decreasing. Forecasts up to 2030 indicate slow recovery and growth of animal numbers at annual rates below one percent.

Strategic priorities for Eastern Europe and Central Asia

Future development will be driven by further privatization, structural adjustments and market liberalization, plus the gradual spread of farming systems characterized by small size and private or family ownership. After almost ten years of reforms and the adoption of more comprehensive transition policies, the transformation of agriculture is most advanced in CSEE countries where agricultural production has started to rise and labour productivity is increasing. In contrast, CIS countries still need to transform their large-scale farm units and eliminate distortions in production, pricing and marketing of 'strategic' products. Two main ways could be envisaged; one leading to small private farms serviced by a medium-sized corporate farm, leasing its land from ex-members and providing contractual services. The alternative would lead to fully independent small farms; services being provided by individuals among them (e.g. tractor owners for machinery services) or by various cooperation mechanisms. Land tenure arrangements would preferably ensure freehold and free transferability of titles, at least for the cultivated land.

In most CIS countries, economic reform has meant the collapse of the previous system – based on state-controlled allocation of raw and processed products – and the subsequent specialization of certain regions or republics in the production of agricultural products. Price and trade policies need rapid improvement, while addressing legal impediments to market development and eliminating informal barriers to trade are equally important. Improving quality by promotion of standards, and fostering the emergence of new types of private small-scale processing industries are also essential. Strengthening local institutions will also be of the utmost importance in trying to encourage and support the development of new marketing structures.

There is substantial scope for both agricultural growth and poverty reduction in the region. With regard to the strategies of poor households for escaping poverty, production intensification holds the greatest promise on a regional scale, followed by enterprise diversification. The overall challenge of reducing hunger and poverty demands three major strategic initiatives. These are all concerned with building the capacities of local institutions – both in the public and private sectors – in order to take advantage of farm restructuring and economic liberalization. In the public sector, this implies acquiring the capacity to switch from a planning role in a command economy system to a supporting and guiding role. In the private sector, it means acquiring the knowledge and skills to operate within an open economy. The proposed inter-linked initiatives are:

Improved resource access: Improved land tenure systems are needed in order to encourage the efficient use of land and the emergence of viable private farm units. Components include: completing land distribution processes; continuing support and broader development of land administration systems; encouraging formal transfer of land, through renting, leasing or sale and through appropriate valuation; and developing real estate management skills.

Expanded market development: Functional markets for agricultural products, inputs and labour are essential. Components include: supporting efficient organizations of producers, traders and processors; investing in market infrastructure (including market and price information systems); improving the quality of food products in order to comply with international norms; and addressing legal impediments to efficient marketing.

Re-oriented and strengthened agricultural services: Viable farming systems require new types of post-privatization services. Components include: the provision of mixed public/private sector advisory services; training; and the dissemination of information in order to improve technical, managerial and marketing skills of privatized farms.

Other measures, such as the rehabilitation of viable irrigation schemes and the establishment of rural finance mechanisms, also merit regional priority. However, they will not operate effectively unless local capacities are first enhanced.

Global challenges, potentials and priorities

System categories and household strategies

Categorizing farming systems on a global basis The 72 farming systems identified in the six developing regions can be grouped into eight major categories (see Chapter 1), based on the characteristics described in the previous chapters, in order to facilitate comparison and integration of development lessons into an overall global strategy for poverty reduction (see Table 8.1). The eight system categories, are: (i) smallholder irrigated farming systems; (ii) wetland rice based farming systems; (iii) rainfed farming systems in humid areas; (iv) rainfed farming systems in steep and highland areas; (v) rainfed farming systems in dry or cold areas; (vi) dualistic farming systems with both large-scale commercial and smallholder farms; (vii) coastal artisanal fishing mixed farming systems; and (viii) urban based farming systems. Except in the case of the dualistic category, smallholder producers dominate these system types. Although the largest single category is that of the wetland rice based systems (of South and East Asia) with an agricultural population of 860 million, the rainfed humid, highland and dry/cold systems together account for over 1400 million people and a much greater area of cultivated land (over 6 billion ha). Interestingly, the three farming system categories with high levels of marketable surplus account for an agricultural population of only 130 million in total.

Relative importance of poverty reduction strategies by system category

The improvement of farm household livelihoods that would be necessary to meet international goals of halving hunger and poverty by 2015 could be derived from five main sources, defined in Chapter 1, which correspond to the principal farm household strategies for escaping from hunger and poverty. These are:

- Intensification of existing patterns of farm production;
- Diversification of production, including the development of market-oriented production and increased value added post-harvest activities such as processing;
- Increased operated farm or herd size, either through consolidation of existing holdings or the extension of farming onto new agricultural land;
- Increased off-farm income to supplement farming activities; and
- Exit from agriculture, often involving migration to urban areas.

The relative importance of these poverty reduction strategies differs between system categories. In aggregate terms, a larger proportion of poverty reduction is expected from improvements on the farm (intensification, diversification and increased farm size) than from off-farm sources (increased off-farm income and exit from agriculture). In the context of farm improvement, diversification is a key strategy for poverty reduction in all eight system categories (and, in fact, is the most important source of poverty reduction in many of these systems). Intensification is key in four system categories, notably those with higher potential such as irrigated, wetland rice and dualistic systems, while increased farm, herd or business size is key only in dualistic and urban based systems.

Millions of farmers are expected to escape poverty by increasing off-farm income, which is second only to diversification as a key strategy for poverty reduction, and is of importance in all systems except the dualistic. The exit of farmers from agriculture within a particular farming system is expected to be an increasingly common phenomenon, and of particular importance among smallholders in rainfed highland and dryland areas, and in coastal artisanal fishing systems.

As indicated above, there are important complementarities between the poverty reduction strategies. In fact, farmers will often intensify and diversify their production simultaneously. Furthermore, these on farm processes create the conditions for the development of the non-farm economy, which in turn stimulates further agricultural growth. On the other hand, poor farm households unable to participate effectively in diversification and intensification processes may well progressively increase the emphasis on off-farm income over time, until they finally abandon agriculture altogether.

A global strategy for hunger and poverty reduction

Key regional initiatives are highlighted as a result of the analysis of farming systems. It is clear that some key initiatives are of importance worldwide, particularly improved resource management and more equitable and secure access to resources. Other initiatives, such as increased small farm competitiveness and re-oriented agricultural services are common, but not universal. Nevertheless, it should be borne in mind that a similar general area of initiative (e.g. sustainable resource management) might have quite distinct components in different regions, in accordance with local needs and priorities.

These initiatives can all be related to the five broad areas of focus employed throughout the book: (i) policies, institutions and public goods; (ii) trade liberalization and market development; (iii)information and human capital; (iv) science and technology; and (v) natural resources and climate. These are explored further below.

Policies, institutions and public goods

- A key challenge in relation to the reduction of hunger and poverty among farm households is the creation and effective delivery of reliable and pro-poor international, national and local public goods, within an environment of secure law and order and enabling policies and institutions. The five most important priority thrusts in this area are seen as
- Establish equitable, secure, transferable and flexible resource user rights;
- Provide sustainable infrastructure to poorly serviced farming systems;
- Reform agricultural policies and strengthen meso level institutions;
- Prioritize support for small-scale farmer managed irrigation schemes; and
- Establish and strengthen targeted safety nets.

Most reviews of policies and institutions suggest that governments should complete the withdrawal of direct public support from viable commercial farming and privatize associated services such as seed production and marketing of some crops. Nevertheless, it is clearly in the public interest that governments should continue to ensure reliable access to relevant public goods by the small farmer sector, as well as promoting the sustainable use of natural resources. Government efforts should be devoted to clear cases of public benefit, including education, public health, and research and extension services addressed to the needs of poor farmers and marginal areas. They should also concentrate on the enforcement of regulations, with a particular emphasis on avoiding barriers to entry for small enterprises. In addition, small farmers require equitable, secure, transferable, yet flexible, resource user rights and sustainable infrastructure – including roads and the structures to support small-scale farmer managed irrigation. Policies and institutions must, therefore, underpin smallholder development, as well as expanding the capacity of private sector service suppliers – this is particularly relevant in Africa and Eastern Europe and Central Asia.

In order for farmers to manage their resources sustainably whilst simultaneously benefiting from Economic liberalization, stronger local and meso-level institutions that involve multiple stakeholders are necessary. Some success has been achieved with the outsourcing of public service and infrastructure provision to private firms, NGOs and universities, thereby achieving efficiency gains. However, local participation is critical for monitoring the private provision of goods and services. Farmers' organizations and the private sector can play a key role in many areas, such as seed multiplication and varietal development.

Exporters' associations can often implement phytosanitary inspection. Research priorities and budgets can be managed through competitive bidding and public-private cost-sharing arrangement.

Targeted safety nets for the poor will continue to be necessary to overcome natural disasters; and may become even more important for farmers who are unable to adjust quickly enough as the transformation of agriculture to market-oriented production accelerates over the coming decades.

Agricultural information and human capital

Three important global priority thrusts, concerned with enhancing the benefits of agricultural information dissemination and use and developing human capacity, have been identified to reduce hunger and poverty:

- Create sustainable systems for generation and dissemination of agricultural information;
- Introduce broad, systems-oriented agricultural training; and
- Support vocational training for off-farm and urban employment.

Globalization, urbanization, and the accelerating pace of technological change, are all increasing knowledge requirements within farming systems. New approaches must be developed to support information flows between farmers and formal knowledge, as well as horizontally among farmers themselves. More thought must also be given to the long-term sustainability and relevance of agricultural information systems. There is little evidence that users are willing to pay enough to make such services self-supporting, while pressure on government recurrent budgets often means that services descend to 'least-cost' solutions once external financing is withdrawn. Private sector participation in information collection and distribution is often essential if services are to be sustainable.

Training and capacity building involve the empowerment of community members – men and women, youths, poor and non-poor – in order to enable them to identify their problems in a systems context, to analyze causes and effects, to assess options and arrive at well-informed decision in order to prepare for a better future. This implies that extension services must reorient their operations by basing them on facilitative rather than prescriptive approaches, with community participation forming the keystone in determining priorities and testing possible solutions. Implementation is likely to involve partnerships between governments, private sector or NGO service providers, civil society organizations and community-based groups.

Educational and training programmes in rural areas have generally failed to recognize the reality that many rural inhabitants, especially the young; will derive part or all of their future incomes from off-farm or urban employment. Greater emphasis must be given to imparting the vocational skills that will assist migrants and those needing to augment agricultural incomes to obtain skilled and semiskilled employment.

Conclusions and ways forward

- Unlock the potential of farmers and their communities
- Support the engagement of civil society partners
- Foster competitive agribusiness and commerce as tools for poverty reduction
- Increase effectiveness of local and national government actions for poverty reduction
- Expand the role of international public goods

Potential options to overcome constraints to crop–livestock intensification

- Producing enough biomass: this can be achieved through the use of cropping technologies (water harvesting, irrigation, improved crop varieties) and intensive farming.
- Introducing compatible and high-value perennial crops; this would generate income for the poor farmers and improve the year-round soil cover.
- Implementing an integrated farming approach: this would help local communities to better address a number of issues at a time. It can also facilitate the search for alternative sources for various issues, e.g., alternative feed and fuel sources to save more crop residues for covering the soil and improving its fertility.
- Enhancing the knowledge of farmers: better management and the efficient use of land and water resources would boost crop and livestock productivity. This can be done through various capacity building schemes such as farmer to farmer informal visits, field visits, agricultural shows, demonstrations, farmers' exchange visits, advertisements, leaflets, posters and booklets, radio programmes, TV programmes, training, awareness-raising especially among policymakers and meetings/workshops (Owenya et al. 2001).
- Promoting participatory learning approaches: farmer field schools, for example, would strengthen farmers' understanding of the principles underlying intensive farming using various inputs and services.

Consumption of forest fruit favours conservation

A study on the consumption of wild fruits in Zimbabwe found that while communally owned land was heavily populated and suffered severe deforestation, the availability and use of the three most favoured fruit species (*Diospyros mespiliformis*, *Strychnos cocculoides* and *Azanza garckeana*) were not affected by deforestation. Fruit trees were not cleared, but were deliberately incorporated into new farmland. (Campbell, B.M. 1987)

Mushroom collection in Siberia

In northern and central Siberia, up to 40 percent of indigenous families engage in mushroom collection. Eighteen species of mushrooms are collected from pine and birch forests across the region. Most are gathered for home consumption, but some people engage in processing and sale of mushrooms in local markets. Up to 100 kg of mushrooms per hectare can be found in the most productive areas, although on average households collect no more than 5 kg of mushrooms per day. (Vladyshevskiy *et al*, 2002)

Parklands in the West African

Sahel Parklands are landscapes in which mature trees occur scattered in cultivated or recently fallowed fields. Across the West African Sahel, the tree *Faidherbia albida* occurs naturally but is actively managed in a traditional system of agro forestry. The tree fixes nitrogen through its roots and has a positive effect on soil fertility. Its pods and seeds are important sources of minerals and nutrients for livestock, especially towards the end of the dry season when other sources of browse are often depleted.

White gold": The shea butter trade in West Africa

The shea tree (*Vitellaria paradoxa* and *Vitellaria nilotica*) grows naturally across the West African Sahel region. There are more than 500 million fruiting shea trees across the production belt, and FAO estimates that total shea nut production is approximately 600 000 tonnes per year. The primary export market for shea butter is in the chocolate and confectionery industry. However, shea is also used as a cooking fat, food accompaniment and skin-care product in West Africa. Harvesting and processing is predominantly a women's activity. Across West Africa about 4 to 5 million women are involved in the collection, processing and marketing of shea nuts and butter, and it provides about 80 percent of their income. In Burkina Faso, exports of shea butter and unprocessed shea kernels brought in CFA 5 billion (US$7 million) in 2000, making it the country's third most important export, after cotton and livestock. (Ferris *et al*. 2001)

Prunus africana bark – from overharvesting to sustainability?

The tree *Prunus africana* grows in the high-altitude mixed forests of Cameroon. Its bark is converted into an extract used to treat benign prostrate cancer, mainly in the United States and Europe. However, because of overharvesting, the Convention on International Trade of Endangered Species (CITES) placed restrictions on its export in 2008. Since then, the government of Cameroon has been working on the development of sustainable use guidelines and preparing an application to CITES to permit harvesting and trade in Prunus bark to resume. (Ndam, N. 2004)

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Water Harvesting Check dams for Climate Resilient Agriculture in Rainfed Regions

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The rainfed regions of India are characterized by aberrant behaviour of monsoon rainfall, eroded and degraded soils with water and nutrient deficiencies, declining ground water table and poor resource base of the farmers. The major constraint is low and unstable yields in rainfed areas with large yield gap. In addition to these, climate variability including extreme weather events resulting from global climate change poses serious threat to rainfed agriculture. In global perspective, the rain-fed agriculture will continue to play an important role in food and nutritional security (Wani *et al.,* 2009, Rockstrom *et al.,* 2007). In developing countries, the average grain yields from rainfed regions is about 1.5 t/ha, compared with 3.1 t/ha in irrigated agriculture (Rosegrant *et al.,* 2002). Rainfed or dryland agriculture is prominent in India, accounting for about 56% of the total cropped area and contributes 87.5% coarse cereals, 87.5% pulses, 77% oilseeds and 65.7% cotton of the country's total production (Shalendra Kumar *et al.,* 2015). The rainfed lands are highly prone to adverse impacts of climate change like frequent droughts and crop failures. Further, the Indian climate, which is predominantly tropical and subtropical with monsoonal high intensity rains expedites land degradation process. In rainfed regions, due to the temporal and spatial variability and skewed distribution of rainfall, crops suffer invariably from moisture stress at one or the other stage of crop growth (Srinivasarao *et. al .,* 2015). Rainwater harvesting both *in-situ* and *ex-situ* is the panacea for mitigating the constraints of rainfed farming. The successful production of rainfed crops largely depends on how efficiently soil moisture is conserved (*in-situ)* or the surplus runoff (*ex-situ)* is harvested stored and recycled for supplemental irrigation as these are inevitable options to sustain rainfed agriculture in changing climatic scenario.

In rainfed regions, rainwater is the main source of water for agriculture but its use efficiency for crop production is low and varies from 30-45%. The Comprehensive Assessment of Water Management in Agriculture for Food and Health has discarded the artificial divide between the irrigated and rain-fed agriculture as none of these systems exist in isolation but are in a continuum from rainfed – rainfed with supplemental irrigation to fully irrigated systems (Molden *et al.,* 2007). The monsoonal country like India, most of the annual rainfall is occurring in 30-40 days distributed in 3 to 4 months. The rainwater harvesting is an old age practice and it is evidenced by the existing tanks and ponds in most of the villages in rainfed regions of India. In recent, the importance of rainwater harvesting in rainfed regions of India has increased due to climatic variability and depletion of groundwater levels due to over exploitation. Rainwater harvesting is a method of inducing, collecting, storing, and conserving surface runoff (Motsi *et al.,* 2004).

The farm pond technology is well proven technology for harvesting of excess rainfall during rainy season and reuse in post rainy season, but its adoption has been quite low due to constraints like high initial cost, and lack of suitable cost effective and durable lining and evaporation techniques. In locations, where natural streams are available, the check dams can be an alternative for runoff harvesting and recycling to cope with climatic aberrations such as mid seasonal and terminal droughts and floods. Check dams are constructed across small streams having gentle slope. The site selected should have sufficient thickness of permeable bed or weathered formation to facilitate recharge of stored water within short span of time. The water stored in these structures is mostly confined to stream course and the height is normally less than 2 m and excess water is allowed to flow over the wall. In order to avoid scouring from excess run off, water cushions are provided at downstream side. To harness the maximum run off in the stream, series of such check dams can be constructed to have recharge on regional scale. Clay filled cement bags arranged as a wall are also being successfully used as a barrier across small nalas. At places, shallow trench is excavated across the nala and asbestos sheets are put on two sides. The space between the rows of asbestos sheets across the nala is backfilled with clay. Thus a low cost check dam is created. On the upstream side clay filled cement bags can be stacked in a slope to provide stability to the structure.

Check dams are constructed to store rain water and silt on the upstream side. Depending upon size of nala, its slope, watershed area and severity of the problem, suitable type of check dam can be selected. Temporary check dams made of locally available material like brushwood, log wood and planks are used in small gullies, mostly in the upper reaches where runoff is less. Semi permanent check dams made of loose boulder, and/or dry stone packing are recommended in small to medium gullies. Gabion check dams are preferred in medium gullies in the middle reaches. Permanent gully control structures/water harvesting structures are used in medium to large gullies carrying more runoff especially in lower reaches. Various parts of the check dam are shown in Fig. 1. The spillway is a weir structure. Flow passes through the weir opening, drops to an approximately level apron and then passes into the downstream channel. The effect of check dams on groundwater recharge, water availability, production, productivity, livelihood improvement were reported by several scholars (Wani *et.al., 2007*, Sharda et al.,2005 , Joshi *et. al*., 2005, Kumar *et. al.,* 2004; Dhyani *et. al*., 2016).

Temporary check dams

For stabilization of gullies through vegetation is a difficult task. Temporary mechanical measures are adopted to prevent washing away of the plantation by large volume of run-off that provides to establish the vegetation. Vegetations once established will be able to take care of the gully. Followings are some such mechanical measures / structures; a) Check Dams; - (i) Temporary check dams, (ii) Brush dam, (iii) Semi permanent check dams. b) Loose Rock Dam c) Log Wood Dam.

Vegetative or live check dams

Vegetative live check dams are constructed in upper reaches of the catchments or watershed. The grasses or baboo type of species can be used as live or vegetative check

Bamboo plantation as live check dams in degraded Mahi Ravines of Gujarat

Earthen check dams

Earthen check dams can be defined as small earthen embankments across gullies or streams to reduce the runoff velocity, stabilization of gullies and store the runoff water. The size of the gully plug/checkdam depends on width length and bed slope of the gully, anticipated runoff and proposed plantations in the gully. The height of the gully plug/earthen checkdam usually kept as 0.9 to 1.5 m, top width 1 m for small gullies and 2 m for medium gullies, side slopes 1:1, and length of the gully plug will be kept as equal to the channel width. The spacing depends upon the gradient of the channel bed. Usually for 3 % slope every 30 m distance gully plug can be constructed. These can be constructed at upper reaches of the catchment or watershed. The benefits of these check dams will be stabilization of gully beds and banks, deposition of sediments and nutrients, water storage thereby enhancing soil moisture and better plant growth. Reduced the runoff and soil loss by 80%.

Field execution (Tips of practical importance)

- Plugs/checks can be constructed just before confluence points of the first streams in second order streams and second order streams in third order streams
- The earth can be dugged in upstream side of the gully plus/earthen checkdams.
- First the location of the plug/check can be marked. Bottom width can be marked. After that the duged soil at upstream side should be placed on the marked location in layer by layer by maintaining the sides sloes of 1:1 and top width can be kept as 1 m for small gullies and 2 m for medium and large gullies.

- Natural or grass sodded outlets will made at one corner to drain the excess water
- Pipe outlets will be made for higher flow rates where natural outlets can not be withstand
- The gully plugs can be sodded by grass or closed spaced bamboo rows in upstream as well as downstream side to strengthen the plug.

Sand bag check dams (Bori bunds)

Bori bunds is a type of embankment constructed across the gullies using polythene bags (empty cement or fertilizer bags) filled with the locally available sand or soil for blocking active and erosion-prone first-order streams. It is an effective method to slow down the speed of flowing water of the stream in any area. Usually where earthen gully plugs is not able to control the runoff flow these structures can be constructed.

The size of the bori bund depends on width, length and bed slope of the gully, anticipated runoff and proposed plantations in the gully. The height of the bori bund usually kept as 0.9 to 1.5 m, top width 0.6 m, side slopes 1:1, and length of the gully plug will be kept as equal to the channel width. The spacing depends upon the gradient of the channel bed. Usually for 3 % slope every 30 m distance one bori bund can be constructed. For uniform distribution of soil moisture to the plantations, minimum spacing and minimum height can be maintained. Medium Gullies and deep gullies with complete sandy soils. The locations, where earthen gully plugs is not able to control the runoff flow (Rao etal., 2012). The benefits will be stabilization of gully beds and banks, deposition of sediments and nutrients, water storage thereby enhancing soil moisture and better plant growth. Reduced the runoff and soil loss by 80%.

Field execution (Tips of practical importance)

- Plugs can be constructed just before confluence points of the first streams in second order streams and second order streams in third order streams

- The earth filled polythene bags of 5 rows at bottom, 3 rows at middle and one row at top has to be kept to maintain the stable slope.
- After keeping these bags, soil has to be filled on top and sides and grass sodding/ sowing is also be done. One end of the bund the top boris should be removed and kept at upstream and downstream to serve as outlet.
- For each bori bund, two rows, one each at upstream and downstream edge bamboo saplings has to be planted with plant to plant spacing of 1 m to strengthen the bund

Construction of bori bunds/sand bag checkdam

Bori bunds/sand bag checkdams covered with the soil

Permanent gully control structures

Permanent Gully Control Structures are necessary where vegetative or temporary structures are not adequate. Permanent Structures such as masonry check dams, flumes or earth dams supplemented by vegetations are provided to convey the run-off over critical portion of the gully. Principal types of permanent structures are drop spillways, drop inlet spillways and chute spillways.

Drop spillway

The drop spill way is a weir structure. Flow passes through the weir opening, drops to an approximately level apron or stilling basin and the passes to the down stream channel Drop spillway may be constructed of reinforced concrete, plain concrete, rock masonry and concrete blocks with or without reinforcing or gabions. The spillway is an efficient structure for controlling relatively low heads, normally up to 3.0 meters.

Drop inlet spillways

A drop inlet spillway is a closed conduit that carries water under pressure from above an embankment to a lower elevation. The usual function of a drop inlet spillway is to convey a portion of the runoff through or under an embankment without erosion. It is a very efficient structure for controlling relatively high gully heads usually above 3.0m.

Chute spillways

A chute spillway is an open channel with a steep slope, in which flow is carried at a supercritical velocity. It consists of an inlet, vertical curve section, steep sloped channel and a out let. Reinforced concrete is widely used to construct chute spillways and adopted particularly to high overfall gullies, detention dams to reduce the required capacity.

Brick/stone masonry check dams

In locations, where natural streams are available in lower reaches of the watershed, the brick/stone masonry check dams can be an alternative for runoff harvesting and recycling to cope with climatic aberrations such as mid seasonal and terminal droughts and floods. The construction of brick stone masonry structures involves high cost without any scheme/ programme the adoptability by these structures is low. The rubber and plastic check dams are the cost effective and easy for construction. These will reduce the construction difficulties. These are easily adopted by watershed management schemes for rainwater harvesting and water management practices for a long period without incurring any substantial maintenance cost.

Brick masonry checkdams

Stone masonry checkdams

Check dams design

The design of check dams includes, hydrologic design, hydraulic design and structural design. Hydrologic design describes inflow rate and runoff amount, hydraulic design that includes determination of suitable dimension of various components of the structure and structural design that includes determination of specification and required strength of construction material considering desired safety.

Three steps in design of check dam are

1. Hydrologic design
2. Hydraulic design and
3. Structural design

Hydrologic Design

Peak rate of runoff and runoff volume is estimated at the site of construction for a particular return period depending upon type of structure (Table 1). Peak rate of runoff may be estimated using Rational formula. Runoff volume may be estimated using runoff factor (strange table) or SCS curve number method.

Table 1. Return periods for different structures

Type of structure	Return period (years)
Storage and diversion dams having permanent spillways	50-100
Earthen dams-storage having natural spillways	25-50
Stock water dams	25
Small permanent masonry gully control structures	10-15
Terrace outlets and vegetated waterways	10
Field diversions	15

Peak discharge is generally computed using rational formula as under:

$$Q = \frac{CLA}{360}$$

where Q = peak discharge (cumec)

C = runoff factor or coefficient

I = rainfall intensity for a duration equal to time of concentration for a particular return period (mm/hr)

A = watershed area (ha)

Hydraulic design

Determination of height of the structure and spillway dimension is important steps in hydraulic design. Standard formula of hydraulic flow is then used to compute dimensions of various components of the structure. The following formula gives relationship between peak discharge and length and depth of the weir.

$Q = 1.711\ L\ h^{3/2}/(1.1 + 0.01F)$

Where, Q = peak discharge (cumec)

L = length of weir (m)

h = total depth of the weir including freeboard (m), and

F = fall (m)

A combination of L and h are computed such that $h/F<0.5$ and $L/h>2.0$. Suitable length of weir is then selected for the existing site conditions. Dimensions of other components are Minimum length of headwall extension, $E = 3h + 0.6$ or $1.5F$ whichever is greater

Length of basin, $L_B = F\ (2.28h/F + 0.52)$

Length of transverse sill, $s_t = h/3$

Length of longitudinal sill, $s_l = h/4$

Height of side wall and wing wall at junction, $J = 2h$ or $F + h + s_t – (L_B + 0.1)/2$ whichever is greater

$M = 2 (F + 1.33h – J)$

$K = L_B + 0.1 - M$

Structural design

This involves selection of materials for construction and respective dimensions of each component of the check dam subjected to hydrostatic pressure, weight of the structure and uplift pressure of water. The structure should be checked for safety against overturning and sliding. The structure should also be tested for compressive and tensile stresses set up in the section. However, table 2 and 3 gives recommended sizes of walls and apron thickness.

Table 2. Apron thickness (cm)

Fall(m)	0.5-1.0	1.0-2.0	2.0-3.0
Concrete	20.0	25.0	30.0
Masonry	30.0	37.5	45.0

Table 3. Bottom and top widths for drop spillway in stone or brick masonry (m)

Fall	Headwall	Sidewall	Wingwall	Headwall extension
		Bottom width (b)		
0.50	0.45	0.30	0.30	0.30
1.00	0.67	0.55	0.40	0.40
1.50	1.00	0.82	0.60	0.60
2.00	1.33	1.10	0.80	0.80
2.50	1.67	1.37	1.00	1.00
3.00	2.00	1.65	1.20	1.20
		Top width (t)		
Minimum	0.45	0.30	0.30	0.30

Table 4. Design example of straight drop spillway

Parameters/Dimensions	Computed		Adopted	
Runoff coefficient, C	0.3		0.3	
Intensity of rainfall, I	120.000	mm/h	120.000	mm/h
Watershed area, A	6.0	Ha	6.000	Ha
Peak discharge, Q	0.600	Cumec	0.600	Cumec
Length of weir, L	2.000	M	2.000	M
Fall/Drop, F	1.500	M	1.500	M
Depth of flow (including freeboard), h	0.337	M	0.35	M
h/F Should be <0.5	0.225		0.233	
L/h Should be >2	5.937		5.714	
Length of basin, LB	2.888	M	2.9	M
Length of Headwall extension, E	2.250	M	2.250	M
Height of transverse sill, s	0.112	M	0.150	M
Height of longitudinal sill, sl	0.084	M	0.100	M
Ht. of wing wall & side wall junction, J	0.674	M	0.700	M
M	2.549	M	2.550	M
K	0.439	M	0.450	M

Stability analysis

Vertical forces

1. Weight of dam per unit length(m), $W = F \rho_m (t + b) / 2$
2. Uplift force, $U = c \rho_w b F / 2$

Horizontal forces

1. $H = \rho_w h^2 / 2$

Moment due to various forces at toe

1. Due to self weight = $[\rho_m t.F. (b - t/2) + \rho_m (b - t) F/2 \ (b-t) 2/3]$
2. Due to uplift force = $U \ 2 b /3$
3. Due to water process = $H \ F/3$

Factor of safety against overturning = M_R / M_O = (+)M / (-) M > 2

Factor of safety against sliding = $\mu \Sigma V / \Sigma H > 1$ ($\mu = 0.75$)

Calculation of stresses

Resultant act at X = $\Sigma M / \Sigma V$

Eccentricity e = b/2 – X

Compressive stress at toe = $\Sigma V/b\ (1 + 6e/b)$

Compressive stress at heel = $\Sigma V/b\ (1 - 6e/b)$

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Addressing Malnutrition with Biofortified Crops

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Present day agriculture has been largely successful in meeting the total calorific requirements of very large poor population in developing countries. During the past few decades, agricultural research along with strong policy support has resulted in a sharp increase in cereal production in developing countries where earlier a large population struggled to secure one square meal a day. Till recently the nutritional concerns were often ignored. Micronutrient deficiencies often known as the 'hidden hunger' go unnoticed even in the developed world and can lead on to life-threatening illnesses. Either caused by a lack of protein (protein-energy malnutrition) or micronutrients such as iodine, vitamin A and iron and zinc (micronutrient deficiency), malnutrition weakens immune systems, exacerbates the effect of childhood diseases such as measles, malaria, pneumonia and diarrhea, and can permanently impair long-term physical and cognitive development. In the developing world, it afflicts over two billion people. Balanced nutrition is not accessible to more than half of the world population predominantly in developing countries. The most common forms of malnutrition are protein energy malnutrition, iodine deficiency disorders, vitamin A deficiency (VAD), iron deficiency anemia and zinc and folate deficiency. Intensive nutritional fortification and supplementation initiative have shown a good impact. Still a lot needs to be done in this direction and biofortification has shown enormous promise. Biofortification, the delivery of micronutrients especially vitamins and minerals via micronutrient-dense crops, offers a cost-effective and sustainable approach, complementing these efforts by reaching out large rural populations. It involves identification of varieties of a crop that naturally contain high densities of desired micronutrients. We can achieve high concentrations of bio-available micronutrients in the edible parts of staple crops through breeding, provided that sufficient genetic variation for a given trait exists, or through transgenic approaches. Research and breeding programs are underway to enrich the major food staples in developing countries with the most important micronutrients: iron, pro-vitamin A, zinc and folate through biofortification. Biofortification relies on the plant's biosynthetic (vitamins) or physiological (minerals) capacity to produce or accumulate the desired nutrients. The biofortification strategy seeks to take advantage of the consistent daily consumption of large amounts of food staples by all family members, including women and children who are most at risk for micronutrient malnutrition. As a consequence of the predominance of food staples in the diets of the poor, this strategy implicitly targets low-income households.

Steps involved in developing a biofortified variety

Various steps involved in developing a biofortified variety include: (i) Identification of genetic variability within the range that can influence human nutrition. (ii) Introgressing this variation into high yielding, stress tolerant genotypes possessing acceptable end-use quality attributes. (iii) Testing the stability of biofortified nutrient accumulation across the target environment. (iv) Release and large-scale deployment of seed of improved cultivars to farmers.(v) Facilitate Dissemination and (vi) Marketing and consumer acceptance. In the absence of a reasonable variability then genetic modification offers a valid alternative. Biofortification is highly feasible approach and for most crops since there is adequate genetic variation in concentrations of beta-carotene, other functional carotenoids, iron, zinc, and other trace minerals in varieties available in germplasm banks to increase micronutrient densities through conventional breeding by a multiple of two for trace minerals and by higher multiples for beta-carotene (Table 1).

Biofortification aims to increase nutrition and yields simultaneously. It has been observed that micronutrient density traits are stable across growing environments and it is possible to combine the high micronutrient density trait with high yield, unlike protein content and yield, which are negatively correlated. The genetic control of target nutritional traits is simple enough to make breeding economical and it is possible to improve the content of several micronutrients together in a single variety. The bioavailability of the extra trace minerals in elite breeding lines is high in *in vitro* and animal tests; tests on human populations are now a high priority. Biofortification provides a feasible means of reaching out to malnourished populations in relatively remote rural areas, delivering naturally fortified foods to people with limited access to commercially-marketed fortified foods, which are more readily available in urban areas. One example of such

Table 1. Genetic variation in concentration of iron, zinc, beta-carotene and ascorbic acid found in the germplasm of five staples (mg/kg) DW basis

Crop		Fe conc. range(mg/kg)	Zn conc. range (mg/kg)	Beta-carotene *** range (mg/kg)	Ascorbic acid range (mg/kg)
Rice,	brown	6-25	14-59	0-1	-
	milled	1-1	14-38		
Cassava	root	4-76	3-38	1-24*	0-380*
	leaves	39-236	15-109	180-960*	17-4200*
Bean		34-111**	21-54	0	-
Maize		10-63	12-58	0-10	-
Wheat		10-99**	8-177**	0-20	-

Note: * FW basis; **including wild relatives; *** range for total carotenoids is much higher an initiative is, BARI released a micronutrient-rich variety - BARIMasur-8 - which is an outstanding lentil line developed from a crossing made between a Bangladeshi lentil cultivar and an ICARDA breeding line. It was selected from among 412 lines supplied by ICARDA. While in the commonly available local varieties, iron and zinc contents vary between 55-62 ppm and 32-41 ppm respectively, this improved variety has iron and zinc contents in the range of 72-75 ppm and 58-60 ppm respectively - a significant gain in micronutrient nourishment. Other advantages of this variety are its enhanced seed yield of 2000-2200 kg/ha as compared to 1050-1100 kg/ha with the previous varieties. Also it's a short-duration variety maturing in 110-115 days, fitting in well with the existing cropping patterns.

The Global Nutrition Report (2014) and the Kigali Declaration on Biofortified Nutritious Foods (HarvestPlus 2014) both highlight the need for multiple complementary strategies to address key micronutritient deficiencies. Combinations of actions are needed because different populations within a country can be reached by different methods and all people need to be reached. The HarvestPlus (a non-profit organization) programme is coordinated by the International Centre for Tropical Agriculture and the International Food Policy Research Institute. It has nine target countries: Nigeria, Zambia, Democratic Republic of Congo, Rwanda, Uganda, Ethiopia, Bangladesh, India and Pakistan. Brazil has also begun introducing biofortified crops.

HarvestPlus scientists have created 150 kinds of 12 food crops, including corn, beans, rice, lentils and wheat. They have shipped the seeds to 30 developing countries, reaching an estimated 20 million people since 2003. The goal was to reach 15 million households worldwide by 2018 and ensure that they were growing and eating biofortified crops such as cassava, maize, orange sweet potato, pearl millet, pumpkin and beans. Harvest Plus expects that the group will reach one billion by 2030.

Table 2. Schedule of product release of biofortfied crops

Crop	Nutrient	Counties of first release	Agronomic trait	Release year
Sweet potato	Provitamin A Mozambique	Uganda	Disease resistance, Drought tolerance	2007
Bean	Iron, Zinc	Rwanda, DRC	Virus resistance, heat and drought tolerance	2012
Peal millet	Iron, Zinc	India	Mildew resistance, Drought tolerance	2013
Cassava	Provitamin A	Nigeria, DRC	Disease resistance,	2011
Maize	Provitamin A	Zambia, Nigeria	Disease resistance, Drought tolerance	2012
Rice	Zinc, Iron	Bangladesh, India	Disease& pest resistance, cold & submergence tolerance	2013
Wheat	Zinc, Iron	India, Pakistan	Disease & lodging resistance	2013

HarvestPlus distributes its seeds through seed companies and sometimes directly to farmers. As of now, released crop varieties are being disseminated through HarvestPlus and its partners in Uganda (orange fleshed sweet potato), Zambia (maize), Nigeria (cassava), the Democratic Republic of the Congo (DRC) (cassava and beans), Rwanda (beans), and India (pearl millet) (Table 2).

Orange-fleshed sweet potato

After screening identified varieties that twice exceeded the target level of 30 ppm of provitamin A, varieties were improved by the International Potato Center (CIP) and National Agriculture Research and Extension System (NARES) scientists to suit local tastes and agronomic conditions. Mozambique and Uganda released high-provitamin A varieties in 2002 and 2007, respectively. Biofortified varieties are now being introduced in many parts of Africa and South America, as well as China.

Maize

Provitamin A maize breeding is led by the International Maize and Wheat Improvement Center (CIMMYT) and International Institute of Tropical Agriculture (IITA) in conjunction with NARES in southern Africa. Germplasm screening discovered genetic variation for the target level (15 ppm) of provitamin A carotenoids in temperate maize, which was then bred into tropical varieties. Recent developments in marker-assisted selection technology have increased the speed and accuracy of identifying genes controlling the traits of interest in maize. Varieties that can provide 25 percent of the estimated average requirement (EAR) for adult women and pre-school children were released in Zambia (3 varieties) and Nigeria (2 varieties) in 2012. Varieties that can provide 50 percent of the EAR are in process of development.

Cassava

Biofortified cassava is being developed for Nigeria and the DRC. The initial breeding target was set at 15 ppm provitamin A. Screening research identified source germplasm from cassava populations in South America, and IITA and the International Center for Tropical Agriculture (CIAT) improved these varieties to be suitable to the African environment and resistant to cassava mosaic disease. Three varieties with sufficient provitamin A to provide 25 percent of the EAR for women and preschool children were released in Nigeria in 2011.

Rice

In many Asian countries, rice provides up to 80 percent of the energy intake of the poor. High-zinc rice varieties for Bangladesh and India are developed by the International Rice Research Institute (IRRI) and the Bangladesh Rice Research Institute (BRRI). The breeding target has been set at 28 ppm zinc in polished rice, an increment of 12 ppm above the baseline zinc concentration of commercially available rice. High-yielding varieties with more than 75 percent of the target are in official registration trials in Bangladesh and India.

A high-zinc rice variety was identified in Brazil and registered for release in 2012 by Embrapa, and a high-iron rice variety was released in China in 2011; research to incorporate the high-zinc trait into this Chinese line continues.

Wheat

The development of high-zinc wheat for India and Pakistan is led by CIMMYT. The initial breeding target for whole wheat was set at 33 ppm zinc, an increment of 8 ppm above the baseline zinc concentration. It is expected that adoption of high-zinc wheat will be driven by its improved agronomic properties compared to current popular varieties, and breeding has focused on both zinc content and resistance to new strains of yellow and stem rust.

Pearl millet

Pearl millet is a regionally important staple in the Indian states of Maharashtra, Rajasthan, Gujarat, and Uttar Pradesh, the target area for biofortified pearl millet. The breeding target was set at 77 ppm iron, an increment of 30 ppm above the baseline. The popular open pollinated variety (OPV) ICTP 8203 was improved to create the first biofortified variety, called ICTP 8203-Fe, which contains the full iron target and was officially released in 2013. Hybrid varieties with up to 100 percent of the iron target are in the development pipeline.

Beans

The target countries for high-iron bean are Rwanda and the DRC; CIAT and the Rwandan Agricultural Board (RAB) lead the breeding process to reach the initial breeding target of 94 ppm, 44 ppm above the baseline. Several "fast track" lines with more than 60 percent of the target level of iron are in delivery. Five varieties of biofortified beans with higher iron levels were released in Rwanda in June 2012. The breeding pipeline includes both large-seeded bush lines and mid-altitude adapted climbing beans.

Advantages of Biofortification approach

- Biofortification is sustainable.
- Biofortification is targeted.
- Biofortification is cost-effective.

Doubling the Farmers' Income

Biofortified staple foods can contribute to body stores of micronutrients such as iron, zinc, and vitamin A throughout the life cycle, including those of children, adolescents, adult women, men, and the elderly. The potential benefits of biofortification are, however, not equivalent across all of these groups and depend on the amount of staple food consumed, the level of micronutrient deficiency, and the micronutrient requirement as affected by daily losses of micronutrients from the body and special needs for processes such as growth, pregnancy, and lactation. Therefore, biofortification alone is unlikely to reduce micronutrient deficiencies in full; it will need to be coupled with other interventions.

The permanent solution to addressing micro-nutrient deficiencies in developing countries will require efforts across multiple government ministries, improvements in health education, adequate supportive policies and the accessibility of diverse diets consisting of fruits, vegetables, legumes, fish, grain and other animal products. Until there is greater investment in agricultural development and rural economic development, alongside improved coordination with education and health interventions, this may be slow to realize.

The substantive points involve the following questions. Which is the targeted year for doubling farmer income? What is to be doubled — is it output, value added or income earned by farmers from agricultural activities? Is it nominal income or real income that has to be doubled? Does the targeted income include only income derived from agricultural activities or would it also include income from other sources? Clarity on all these points is important to assess the possibility of doubling the income of farmers as envisioned by the PM.

Conclusions

Biofortified crops are bred to have higher amounts of micronutrients and can help provide essential vitamins and minerals. They provide a low cost, sustainable and permanent solution to problems related to malnutrition. To date, orange-flesh sweet potato lines with high levels of b-carotene (over 200 mg/g) have been identified, and beans with improved agronomic traits and grain type and 50–70% more iron have been bred through conventional means. Because of regulatory and political restrictions on the use of transgenic approaches, and because significant progress can be made through conventional breeding, 85% of HarvestPlus resources are currently devoted to conventional breeding. Transgenic approaches are in some cases necessary and, in some cases, potentially advantageous compared with conventional breeding. The best-known example is Golden Rice; b-carotene has not been identified in the endosperm of any rice variety, and an advanced transgenic line containing 37 mg/g carotenoid, of which 31 mg/g is b-carotene, is now available

One such example is Golden Rice which contains higher amounts of beta-carotene, with potential benefits for 250 million children who risk blindness due to vitamin A deficiency. Similarly, rice with higher amounts of iron could offer significant benefits to 1.4 billion women who suffer from anemia. Biofortification is yet to be fully scaled-up in a single country, but much evidence and experience has been assembled to support its eventual effectiveness. Policies to support cross-sectoral implementation at all levels, as well as increasing the evidence base, will contribute to ensure that biofortification is a cost-effective investment in community nutrition.

- Some of the suggested action points to make it effective to deal with widely prevalent malnutrition are as under:
- Make enhanced mineral and vitamin content of the edible portions of new crop varieties core breeding objectives at agricultural research centers, in addition to yield and other agronomic characteristics

- Invest in developing cultivars with multiple micronutrients to capitalize on the synergistic effects between micronutrients.
- Develop further efficacy trial evidence for biofortified crops, in particular with respect to the nutritional status of mothers going into pregnancy and for young children.

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