

sources, more dominant crops and cropping systems along with their sowing windows; livestock, poultry and fisheries information; production and productivity statistics; major contingencies faced by the district and digital soil and rainfall maps and (b) the detailed strategies for weather related contingencies anticipated in crops/cropping systems such as delay in onset of monsoon of different duration; mid-season monsoon breaks resulting in drought both in rainfed and irrigated situations and adaptation strategies for weather related extreme events. These contingency plans contain information on alternate crop varieties/crops to be chosen in case of delay in onset of monsoon or early season drought and also on agronomic measures for mid and terminal season droughts. Further, strategies for contingency situations in livestock, poultry and fisheries have also been included (Rajendra Prasad *et al* 2013). Various interventions need to be taken during delay in canal water release and its later release in irrigated regions and related aspects are also dealt.

### Status of Contingency Plans

The district based contingency plans are prepared for 623 districts of the country and hosted on ICAR / DAC websites (<http://farmer.gov.in/>, <http://agricoop.nic.in/acp.html>, <http://crida.in/> and circulated to all state agriculture departments (Fig 2) and state-wise status of preparation of the plans is presented in (Fig 3).



Fig. 2. Status of district agricultural contingency plans as on October 2017

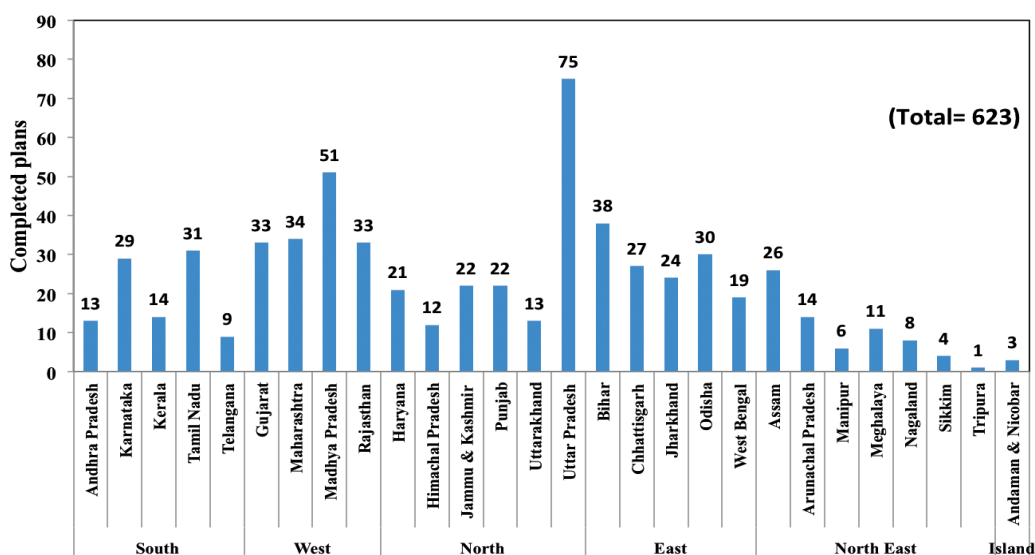


Fig. 3. State-wise status of district agricultural contingency plans as on October 2017

### Operationalization process

To operationalize the contingency plans, extensive planning both at district and state level is needed with a well-organized coordination and facilitation by all relevant departments both at State and Central level. In order plans relevant on near real-time basis, interface meetings were organised with concerned line departments of the State Government before the commencement of *kharif* season, 2014 (in 4 states), 2015 (in 11 states and a national consultation), 2016 (in 12 states) and 2017 (in 12 states) across India. During 2017, for the first time, an interface meeting for *rabi* was also organized in Madhya Pradesh. The seasonal forecast for southwest monsoon made by IMD and South Asian Climate Outlook Forum and other International agencies was utilised to make an analysis of the prospects of monsoon and the measures to be taken up to face the scenarios. During 2014 and 2015, it was the widespread drought prediction and during 2016, emphasis was on tackling excess rainfall scenario in some parts of the country like western and central states and mid or end of season droughts in eastern region (Fig.4). The meetings are conducted jointly by DAC and ICAR in various states and participants include senior officials of departments of agriculture, KVKs, SAUs, seed agencies and other stakeholders. It is always ensured that senior officials attend these meetings so as to take necessary policy interventions to address issues. The deliberations cover drought management, suggested alternative crops, seed availability, and preparedness strategies of line departments.



Fig 5. National Level Consultation meeting on Preparedness for agriculture contingencies held at ICAR- CRIDA, Hyderabad on 24<sup>th</sup> April 2015



Fig 6. ICAR, DAC Interface meeting with Department of Agriculture, Government of Karnataka on 19<sup>th</sup> May at GKVK, Bengaluru



Fig. 4. State-level interface meetings to enhance the preparedness for agriculture contingencies

The DACPs, due to its wide coverage in terms of sectors and weather aberrations, could be implemented through different developmental initiatives such as NMSA, IWMP, PMKSY etc.

As part of making the agriculture plans more dynamic, a plan for post rainy season (*rabi* season- as it is called in India) is prepared for enhancing the crop production in the season through suggestion of alternate crops such as pulses, oilseeds etc. (Srinivasarao *et al.*, 2015). A process has been developed to assess the ground water recharge based on weekly rainfall and their deviation from normal and suggestions were made on cropping pattern to be followed (Srinivasarao *et al* 2014, Srinivasarao *et al* 2016, Srinivasarao and Rao 2016).

### Impacts of contingency plan implementation

The experiences of some of the states in implementing the contingency crop plans in consultation with SAUs and ICAR and their impacts are summarized below:

- Despite the deficit rainfall (-20 to -59% of normal) in 30 districts out of 51 districts in Madhya Pradesh during 2014-15 cropping season the total sown area in the state increased from 4.621 million ha to 5.471 million ha, resulting in total food grain production increase from 8.353 to 9.599 million MT. Productivity of soybean, total oilseeds and total pulses in Madhya Pradesh increased from 0.733 to 0.937 t/ha, 0.52 to 0.6 t/ha and 0.75 to 0.94 t/ha, respectively.

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- Though regions East Gujarat, Central Gujarat, Kutch and South Gujarat received 77 to 88% of normal rainfall during 2014-15, the impact of deficit rain on area and production during the year was negligible except for groundnut, sorghum and pearl millet in Gujarat.
  - The deficit monsoon situation during the year 2014-15 was managed in Karnataka by (a) encouraging the sowing of maize, cotton, pearl millet in unsown areas of sorghum, pigeon pea, groundnut and sunflower; (b) encouraging farming community to take up land configuration, soil management practices; (c) utilizing the common property resources for fodder production and drought safety net programmes i.e., crop insurance.
  - Promotion of community nurseries for rice seedlings to overcome the delayed sowing of paddy on a village basis was the major intervention initiated to meet the demand of the entire village. Similarly, lining of ponds and strengthening of bunds were promoted for effective water storage in Jharkhand.
  - Additional power supply for irrigation purpose to maize crop at critical growth stages in Warangal district, promotion of *in-situ* conservation measures, promotion of short duration rice varieties (MTU 1011 rather than *Sonamasuri*) in case of delay in monsoon, change in sowing practices in rice i.e., direct seeded rice and drum seeded mechanism, crop diversification from cotton to soybean, green gram, groundnut, integrated farming systems as a flagship program in rain fed areas and practices of growing cotton with micro irrigation were some of the major interventions taken up during 2014-15 to overcome delayed monsoon in Telangana. Such real time responses and quick actions impact positively to protect the existing crop and bring overall stability to agriculture production systems (Srinivasarao *et al.* 2016; 2010).
  - *In situ* water conservation measures on large scale, micro irrigation technologies, high density planting of *desi* varieties of cotton, raising soybean with broad bed furrow technology, mulching in horticultural crops, sprinkler irrigation for soybean, hybrid pigeonpea promotion and use of greengram as substitute for soybean were the major interventions promoted during 2014-15 to overcome the adverse effects of delayed monsoon in Maharashtra.
  - In Andhra Pradesh, during 2014-15, measures such as (a) campaign to sow the crops only after the soil soaking rains were received (b) widespread publicity about contingency crop plan through scrolls in all local TV channels (numbering 14) (c) promotion, on a mission mode, of direct seeded/ drum seeded rice cultivation covering 4 lakh ha of rice cultivated area out of a total of 1.6 million ha (d) sowing of horsegram seed in unsown areas of groundnut in Anantapur district (e) growing fodder crops as intercropped in horticultural plantations, (f) flood waters diversions to Rayalaseema region to enhance the ground water recharge and to irrigate horticultural crops were taken up to overcome weather aberrations such as delayed monsoon onset and delay in release of canal water because of rain deficit.
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- During 2015, a successful strategy followed by Government of Andhra Pradesh was to complete the river linking of Krishna and Godavari rivers and diverting Godavari river waters to Krishna delta for rice cultivation. An estimated supply of about 300mm in addition to rainfall could save the produce worth of several crores in both *kharif* and *rabi* season in Krishna eastern and western delta respectively
  - The Krishi Bhagya scheme in Karnataka and large scale land treatment through machinery in Maharashtra helped in conservation of water both *in-situ* and ex-situ helped in protecting the crops during 2015.
  - Initiatives such as encouraging the farmers to cultivate pulses and oilseed crops in mid and uplands in Jharkhand helped farmers to cope up with deficient rainfall season.

## Conclusions

In order to address the climate variability/ change, a coordinated effort by Ministry of Agriculture, Indian Council of Agriculture Research through NARES along with state department of agriculture was started on a continuous basis to provide suitable contingency plans. The preparation and implementation of contingency plans is the way chosen by both federal and state governments as an important adaptation measure to make the agriculture sector more resilient in the country. Anticipatory research is needed to cope with such weather abnormalities as dry spells, high rainfall, hailstorms etc. With time, thorough protocols would have to be put in place where by meteorological division and agricultural research systems provide valuable inputs through advisories to farmers through real-time collection and analysis of weather data at micro level and the support for implementation of advisories would be ensured by extension agencies.

## Way Forward

- 1) The overall implementation strategy of contingency plans involves (a) initial preparedness, (b) real time response to weather aberrations, and (c) relief and rehabilitation. The district agricultural contingency plans (DACP) are technical documents detailing the interventions to be taken up by individuals/line departments in the face of various weather aberrations. With climate change looming large, as witnessed during last few years across different states in India, it is necessary to make these plans dynamic by updating the information on: (a) new technologies developed, (b) improved seed varieties, (c) linkage with new developmental programmes and (d) experiences on handling the recent weather aberrations across states etc.
- 2) However, overall strategy need to be developed at DAC, Ministry of Agriculture and Farmers Welfare, Government of India, by setting up an institutional mechanism such as nodal cell at DAC and at agriculture department of various state governments for implementation of these need based contingency measures. There is no need to implement the plan in totality, need based and depending upon rainfall situation, interventions need to be prioritized. ICAR-CRIDA in association with entire NARS has a role in technical backstopping,

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updating plans periodically, knowledge dissemination, capacity building, sensitization of department functionaries for enhancing their capacity to implement the need based plan components.

## References

- Rajendra Prasad., Ravindra Chary, G., Rao, K.V., Prasad, Y.G., Srinivasa Rao, Ch., Ramana, D.B.V., Sharma, N.K., Rao, V.U.M. and Venkateswarlu, B. 2013. District Level Contingency Plans for Weather Aberrations in Himachal Pradesh. CSK HPKV, Palampur, HP and Central Research Institute for Dryland Agriculture. Hyderabad-500 059, India. p.222.
- Srinivasa Rao, Ch., Prasad, Y.G., Ravindra Chary, G., Rama Rao, C.A., Rao, K.V., Ramana, D.B.V., Subba Rao, A.V.M., Rajbir Singh., Rao, V.U.M., Maheswari, M. and Sikka, A.K. 2014. Compensatory Production Plan for *Rabi* 2014. CRIDA Technical Bulletin 2/2014. Central Research Institute for Dryland Agriculture and Natural Resource Management Division, ICAR, Hyderabad. p.80.
- Srinivasarao, Ch., Lal, R., Prasad, J.V.N.S., Gopinath, K.A., Singh, R., Jakkula, V.S., Sahrawat, K.L., Venkateswarlu, B., Sikka, A.K., Virmani, S.M. 2015a. Potential and Challenges of Rainfed Farming in India. *Advances Agronomy* 133, 113-181 p.
- Srinivasa Rao, Ch., Rao, K.V., Ravindra Chary, G., Prasad, Y.G., Subba Rao, A.V.M., Ramana, D.B.V., Prasad, J.V.N.S., Rama Rao, C.A., Pankaj, P.K., Gopinath, K.A., Kandpal, B.K., Maheswari, M., Rao, V.U.M. and Sikka, A.K. 2015b. Compensatory *Rabi* Production Plan-2015. Technical Bulletin 1/2015. Central Research Institute for Dryland Agriculture and Natural Resource Management Division, Indian Council of Agricultural Research, Hyderabad-500 059, India. p.66
- Srinivasa Rao, Ch., Venkateswarlu, B., Sikka, A.K., Prasad, Y.G., Chary, G.R., Rao, K.V., Gopinath, K.A., Osman, M., Ramana, D.B.V., Maheswari, M. and Rao, V.U.M., 2015c. District Agriculture Contingency Plans to Address Weather Aberrations and for Sustainable Food Security in India. CRIDA-NICRA Bulletin 3/2015. ICAR-Central Research Institute for Dryland Agriculture, Natural Resource Management Division, Hyderabad-500 059, India. 22p.
- Srinivasa Rao, Ch., and Rao, K.V. 2016. District Agricultural Contingency Plans for Managing Weather Aberrations and Sustainable Agriculture. CRIDA Brochure (2016). ICAR-Central Research Institute for Dryland Agriculture, Natural Resource Management Division, Hyderabad-500 059, India. 8p.
- Srinivasarao, Ch., Chary, G.R., Rani, N. and Baviskar, V.S. 2016. Real time implementation of agriculture contingency plans to cope with weather aberrations in Indian agriculture. *Mausam*. 67:1, 183-194 p.
- Srinivasarao, Ch., Venkateswarlu, B., Dixit S., Veeraiah, R., Rammohan, S., Sanjeev Reddy, B., Kundu Sumanta. and Gayatri Devi, K. 2010. Implementation of Contingency Crop Planning for Drought in Tribal Villages in Andhra Pradesh: Impacts on Food and Fodder Security and Livelihoods. *Indian Journal of Dryland Agricultural Research and Development*. 25(1):23-30.



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## Cost cutting techniques for insect pest management

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Crop production in rainfed regions is by nature dependent on monsoon behavior and is therefore highly risky. Important factor that affects crop production is the incidence of pests and diseases apart from, soil productivity, climate and socio-economic conditions. Considering the poor capacity of the farmers to invest on plant protection measures, the incidence of pests and diseases often leads to significant losses of productivity and income to the farmers. Thus, there is considerable scope to develop a system that is diverse and less prone to pests and diseases (Baliddiwa, 1982 and Risch, 1983). Low external input IPM (LEIIPM) seeks to optimize the use of locally available resources by combining the different components of farming system which is the major crux of Low External Input for Sustainable Agriculture (LEISA). In recent years, the value of low external inputs and traditional techniques including non-chemical alternatives, have been tremendously increased and they are viewed as technology options that could help create sustainable systems and decrease or avoid the needs for expensive and undesirable chemical inputs. These options are based on natural crop protection approaches that make use of the diversity found in nature itself. Many countries have initiated IPM programme and due emphasis is given to Low external input IPM as a part of LEISA. A range of treatments cultural, mechanical, crude extracts and different ITK techniques which are proven to be effective were identified and integrated as IPM modules and evaluated in terms of pest control and economics. It was expected that to provide usable cost effective pest control package, which in turn can be used for organic farming also.

### Components of IPM

IPM is defined as integration of various pest control measures in a compatible manner so as to keep the insect pest population well below the economic threshold levels. The objective of the IPM is to reduce the insect pests and to achieve the higher production and productivity. If several components of IPM are integrated properly, the cost effectiveness can also be achieved with higher benefit cost ratio. The details on effectiveness of various components of IPM are discussed here-

- **Summer ploughing** – Adoption of summer ploughing and preparatory cultivation during April-May months will facilitate the destruction of various insect pests. Several dormant stages of insect's viz., pupae of moths, root grubs etc. which live or hide in the soil get exposed to higher temperatures of summer and get killed. In addition to this, the exposed resting stages get devoured by the predators like birds and cause the reduction of pest incidence in the cropping season.

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- **Provision of preventive barriers:** Digging of 30-60 cm wide and 60 cm deep trenches or erecting 30 cm height tin sheets barriers around the fields is useful to prevent the incidence of insect pests like red hairy caterpillars, swarming caterpillars and other army worms from one field to another field.
  - **Bonfire on field bunds:** with the onset of monsoon, the emergence of major insect pests like red hairy caterpillars is noticed and adoption of bonfires on field bunds on community basis trap the phototrophic nocturnal moths.
  - **Seed/Seedling treatment:** Seed treatment with bio-fungicides such as *Trichoderma*, *Pseudomonas*, *Metarhizium* alleviates biotic stress in germinating seeds and seedlings. This treatment controls the spread of pests and diseases either from seed/seedlings thus enhancing plant growth and yield.
  - **Erection of sticky traps:** In vegetables and in irrigated dry crops, erecting either yellow or white sticky traps painted with either castor oil or grease just above the crop canopy after germination of seeds helps to monitor the incidence of sucking pest viz., aphids, whiteflies and to manage them.
  - **Guard crops/Border crops:** Secondary plants grown within or bordering the primary crop for the purpose of protecting it from insect pest and disease outbreak are often referred to as guard/ protector crops or border crops. Seven to ten days before sowing of main crop by sowing the seeds of either jowar, maize or bajra @ 3 to 4 rows around the main crop to prevent the spread of insects and also for the development of beneficial insects
  - **Erection of bird perches:** In vegetables and in irrigated dry crops 15-20 days after germination of seeds by erecting 15-20 traps per acre just above the crop canopy to attract the predatory birds so that they prey upon harmful grown up caterpillar.
  - **Growing trees/shrubs on field bunds:** Growing of trees/shrubs (Neem, Tamarind, Glyricidia etc.) on field bunds ensure that they prevail all the time to serve as bird perches, bio-fence and also to get some revenue
  - **Pheromone Traps:** A pheromone is an ecto-hormone secreted by the insect pest to communicate/attract opposite sex/species. A pheromone trap is a type of insect trap that uses pheromones to lure insects. Sex pheromones and aggregating pheromones are the most common types used. During flowering stage of crops by erecting 10-15 pheromone traps per acre helps to protect the crop from lepidopteran insect pests (*Helicoverpa armigera*, *Spodoptera litura* etc.)
  - **Trap crops:** Growing of susceptible or preferred plants by important pests near a major crop to act as a trap and it is treated with insecticides. Trap crop may also attract natural enemies thus enhancing natural control. The sowing/planting of trap crop (marigold, mustard or castor) will be done around the main field prior to the sowing of main crop (Tomato, Cole crops, Sunflower). Trap crops attract insect pests like *Helicoverpa armigera* and *Spodoptera litura*, *Plutella xylostella* to lay eggs on them.
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- **Crop rotation:** Crop rotation is most effective practice against pests that have a narrow host range and dispersal capacity. The continuous availability of food supply is the most important factor which causes the increased incidence of insect pests (spotted bollworms, pink bollworm etc.) with narrow host range. Lady's finger followed by cotton will suffer from increased infestation of pests. Hence if a non-host crop is grown after a host crop, it reduces the pest population. e.g. Cereals followed by pulses. Cotton should be rotated with non-hosts like maize or soybean to minimize the incidence of insect pests. Groundnut with non-leguminous crops (maize or sorghum) is recommended for minimizing the leaf miner incidence.
  - **Crop-crop diversity:** Crop diversity is a situation where in different crops are grown simultaneously. Crop-crop, crop-border and crop-weed diversities are different forms of crop diversity. Intercropping and mixed cropping systems are more popular forms of crop-crop diversity practiced in rainfed agriculture. The diversified system provides less pest-prone situation compared to monoculture. Pest pressures may be reduced in diversified systems for various reasons, most important being the encouragement of beneficial insect diversity and abundance and reduced ability of pests to locate their preferred feed. Biotic, structural, chemical and micro climatic factors apparently constitute associational resistance, which probably reduce the pest infestation.
  - **Cover crops:** Cover crops such as cucumber, horse gram, cluster bean increases the retention of soil moisture in the alfisols and thus results in reduction of termite incidence. This was followed by higher occurrence of natural enemies.

### **Findings at ICAR-CRIDA**

The concept of superimposing various pest management technologies is much easier and cheaper for the farmer to manage the insect pests easily on diversified cropping system rather than in monocultures which are more prone to pest incidence and require considerable investments in pest management. Low external input IPM (LEIIPM) seeks to optimize the use of local available resources by combining the different components of farming system.

### **Economics of integrated pest management in pigeonpea**

Insect pests are one of the major factors carrying heavy yield losses in rainfed crops, especially pigeonpea and cotton. In order to develop means for achieving pest management in a manner that does not harm environment and is cost-effective, efforts were made to develop integrated pest management (IPM) modules. The effectiveness and economics of such IPM modules in pest management in case of pigeonpea are described here. Different components of IPM were evaluated individually and in combination in order to identify most effective module for managing the major pest in pigeonpea at CRIDA. Application of NPV, NSKE, HaPV, mechanical collection, erection of bird perches and chemical sprays are the components that were included in the IPM. Two different IPM modules were specifically tested with the sequential application of effective treatments and compared with chemical control of pests.

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IPM-1 module included sequential sprays of NPV @ 500 LE ha<sup>-1</sup> followed by one spray of insecticide and NSKE 5 per cent. IPM-2 module comprised two rounds of NPV @250 LE ha<sup>-1</sup> +NSKE 2.5 per cent with one spray of insecticide in between. Both the modules included erection of bird perches. These practices were evaluated for the grain damage, grain yield and economics in a two-year study. The findings indicated that the grain damage by lepidopteran borers was significantly less in both the IPM modules (6.67%). The damage did not vary significantly among the rest of the treatments *viz.*, HaNPV (15.67%), NSKE (17.00%) and mechanical collection (18.67%) the untreated check recorded significantly highest per cent of grain damage (32.33%) . the grain damage by pod fly was significantly less in IPM module I (9.67%) and was on par with chemical control (10.67%) . IPM module II (13.33%) was the next best. The grain yield of pigeonpea were also more in IPM modules in both the years (12.94 -14.17 q ha<sup>-1</sup> in IPM II). The insecticide spray increased the grain yields (9.77 and 9.51 q ha<sup>-1</sup> in first and second years) and was on par with HaNPV (9.55 and 9.27q ha<sup>-1</sup>) The NSKE (7.14 and 7.83 q ha<sup>-1</sup> in first and second years) was on par with the rest of the treatments which did not record significant higher yields over untreated check excepting NSKE in second year.

The incremental benefit-cost ratios computed for these practices also indicated that the IPM modules were more profitable. IPM module I and II recorded IBCRs 8.96 and 8.75 followed by insecticide (7.19) and NSKE (5.19) and mechanical collection (3.04) in first year. In second year also, IPM modules II (10.39) and I (9.13) registered higher CBR than the rest of treatments. NSKE application and insecticide with incremental benefit-cost ratios of 7.46 and 6.56 were found to be next best. The erection of bird perches showed better IBCR (5.71) than the rest of treatments. The predator population also varied significantly across treatments at three and seven days after each application untreated check had higher number of overall mean predator population (7.28) followed by IPM module II (6.06). The insecticide sprayed plots had 4.94 populations.

## Conclusion

The challenge in natural crop protection is to have simple and low-cost technologies that are able to regulate pests and diseases and to reduce or completely avoid the problem of contamination by agrochemicals. One such natural crop protection approach is based on the use of plants with biological control properties. These options were found to be cost effective. The efficacy of individual components was well known and documented by several authors. Intercropping offers farmers the opportunity to engage nature's principle of diversity on their farms. Spatial arrangements of plants, planting rates, and maturity dates are to be considered when planning intercrops. Intercrops can be more productive than growing pure stands. Many different intercrop systems are known and including mixed intercropping, strip cropping, and traditional intercropping arrangements. The merits of intercropping and use of intercropping as a tool of pest management is well documented (Srinivasa Rao *et al.*, 2012). Pest management benefits can also be realized from intercropping due to increased diversity. The efficacy of these botanical extracts in a combination of bird perches and mechanical collection of larvae on a diversified cropping system in an integrated manner with a specified sequential way in the form of Low external input IPM was

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not available. Higher MRR in LEIIPM modules is due to either low or no costs involved in the components used for pest control. These modules also facilitated the multiplication of predators also as *in situ* culturing of natural enemies is possible in case of diversified crops and the other adopted pest control options are eco friendly in nature.

## References

- Baliddawa, C.W. 1985. Plant species diversity and crop pest control – An analytical review. *Insect Science and its Application* 6: 479-487.
- Risch, S.J., Andow, D. and Alteri, M.A. 1983. Agro ecosystem diversity and pest control: data tentative conclusions and new research directions. *Environmental Entomology* 12: 625-629.
- Srinivasa Rao, M., Rama Rao, C.A., Srinivas, K., Pratibha, G., Vidya Sekhar, S.M., Sreevani, G. and Venkateswarlu, B. 2012. Intercropping for management of insect pests of castor, *Ricinus communis*, in the semi-arid tropics of India. *Journal of Insect Science*, 12:14.



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# GIS for Water Harvesting Structures Planning and Management

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Erratic rainfall and dry spells are very common in drylands across the globe and it affects the crop yield drastically. Rainwater harvesting and providing one or two supplemental irrigation to crops during prolonged dry spells which coincides with the critical growth stages of the crop can increase the yield significantly. Under the changing climatic conditions, changes in the frequency and distribution of rainfalls are reported (Rao *et al.*, 2017). According to the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC), the annual average river runoff and water availability are projected to increase by 10-40% at high latitudes and in some wet tropical areas. It may decrease by 10-30% over some dry regions at mid-latitudes and in the dry tropics, some of which are presently water-stressed areas (Nohara, 2006; Yaghoubi *et al.*, 2016). Under these changing climatic scenarios, the distribution of rainfall will vary spatially and influence the runoff potential for rainwater harvesting and hence, special attention is needed for the future planning of these water resources. Planning of soil and water conservation interventions needs data of runoff and soil loss which are scarcely available in developing countries. Hence modeling of runoff and soil loss is very essential for ungauged areas for their sustainable development (Sanjay *et al.* 2010). SCS-CN is widely used for the quick and accurate estimation of runoff and RUSLE is for estimating soil loss from ungauged watersheds (Patil *et al.*, 2008; Rejani *et al.*, 2016). SCS-CN method coupled with GIS helps to estimate the runoff spatially and temporally (Nandgude *et al.*, 2014; Rejani *et al.*, 2015a). Similarly, RUSLE coupled with GIS helps to estimate the soil loss. The spatial variability of runoff and soil loss are very essential for planning *in-situ* soil and water conservation interventions and water harvesting structures in catchments (Rejani *et al.*, 2015b; Rejani *et al.*, 2017). Identifying the suitable sites for *in-situ* and ex-situ soil and water conservation interventions with the help of survey is one of the giant tasks for planners. Considering the time consumption for conventional geographical surveys for identification of potential sites, a methodology was developed using GIS techniques to find the suitable locations for different soil and water conservation interventions required for increasing the crop productivity.

## Methodology

### Planning interventions based on soil loss

The interventions could be selected based on soil loss as shown in Table 1 (Reddy *et al.*, 2005). The runoff and soil loss can be measured in the fields using tipping bucket or coshokton wheel and on rivers or streams using automatic gauge recorders (Fig.1a). In the absence these data, estimations are preferred.





*Runoff and soil loss recording using coshokton wheel and its accessories*



*Tipping bucket type runoff recorder  
Fig.1a. Runoff recorders used in experimental fields*

**Table 1. Recommended conservation measures based on soil erosion in Telangana and AP (Source: NBSS & LUP)**

Soil loss	Districts	Recommended conservation measures
Priority I - (40-80 t/ha/ yr)	Parts of Cuddapah, Visakhapatnam, Adilabad, Vizianagaram, Srikakulam, East Godavari, Khammam, and small areas in other districts	Soil conservation measures and afforestation. Recommended soil conservation measures - contour or staggered trenching on foot hills, plugging of stream courses with rock, gabion structures or concrete masonry check dams in non-arable areas. If depth of the soil is more, bench terracing may be practiced. Agro-forestry, silvipastoral and agri- horticultural systems, plantation or covering with trees or grasses.
Priority -II (20-40 t/ha/ yr)	Parts of Adilabad, Cuddapah, Chittoor, Anantapur, Prakasam, Khammam, Nizamabad, East Godavari, Rangareddy, Vizianagaram, small areas in other districts	In arable deep soils, contour bunds with open ends/waste weir, graded border strips, waterways with drop structures, vegetative bunds, agro-forestry species in the upstream side of the bunds are recommended. On non-arable lands including gullied lands, gully stabilization structures like check dams and gabion structures, farm ponds, contour trenching and planting of forestry species like neem, babul and horticulture crops. In black soils, graded bunds with waterways, farm ponds, gully stabilization structures like check dams, gabion structures and horticultural crops such as pomegranate, amla and guava are recommended.
Priority -III (15-20 t/ha/ yr)	Parts of Anantapur, Cuddapah, Adilabad, Chittoor, Prakasam, Kurnool, Visakhapatnam, Nizamabad, Karimnagar and small areas in other districts	Graded bunds with waterways to check erosion and to conserve moisture, water harvesting structures like farm ponds, management practices like broad bed furrow (BBF), raised and sunken beds are to be adopted as permanent systems in black soils. For red soils, contour/ graded bunds with outlet, graded border strips, farm ponds etc.

Priority -IV (<15 t/ha/ yr)	Maximum area in Mahabubnagar followed by Kurnool, NaIgonada, Anantapur, Prakasam, Khammam, Nellore, Warangal, Guntur, Chittoor, Karimnagar and other districts	Agronomic measures like contour cultivation, strip cropping, proper crop rotations, mulching, planting of grasses for stabilizing <i>bunds</i> , ploughing and inverting the soil. Mixed cropping of shallow and deep-rooted crops can be adopted, watershed-based approach to harvest available water through farm ponds and percolation tanks. Vegetative bunds and management practices like broad bed furrow and raised sunken beds may be followed. Agri- horticultural system to cover the areas may be adopted.
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### Estimation of soil loss using RUSLE

After delineating the watersheds using DEM (Fig.1b), soil loss was estimated using RUSLE (eqn.1) which depends on rainfall, soil (Fig.2), land slope (Fig.3), land use land cover (Fig.4) and crop management practices as shown in Flow chart (Fig.5) (Rejani *et al.*, 2016).

$$A = R K L S C P \quad (1)$$

where  $A$  = average annual soil loss ( $\text{t ha}^{-1} \text{y}^{-1}$ );  $R$  is the rainfall-runoff erosivity factor ( $\text{MJ mm ha}^{-1} \text{h}^{-1} \text{y}^{-1}$ ) (Eqn. 2 to 5);  $K$  is the soil erodibility factor ( $\text{t ha h ha}^{-1} \text{MJ}^{-1} \text{mm}^{-1}$ );  $LS$  is the slope length factor (dimensionless) (Eqn. 3);  $C$  is the cover management factor (dimensionless, values ranged from 0 and 1.0); and  $P$  is the conservation practices factor (dimensionless, values ranged from 0 and 1).

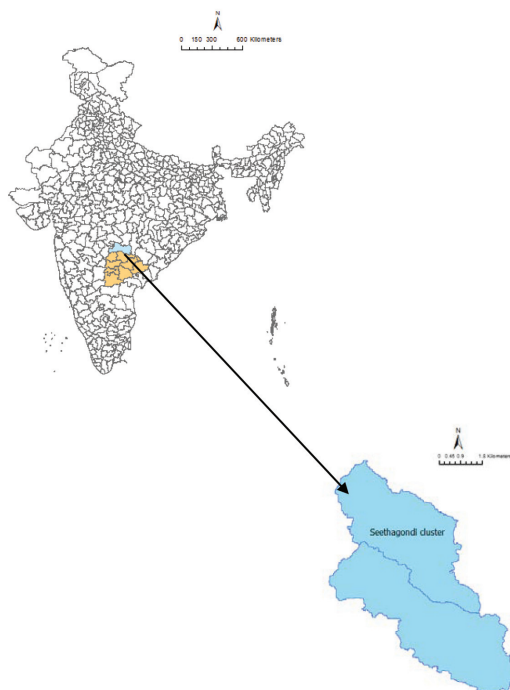
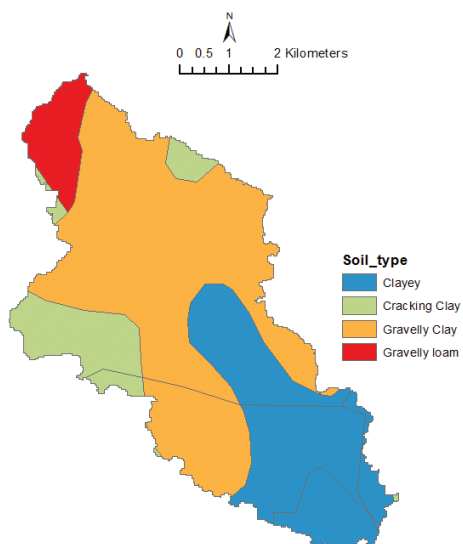
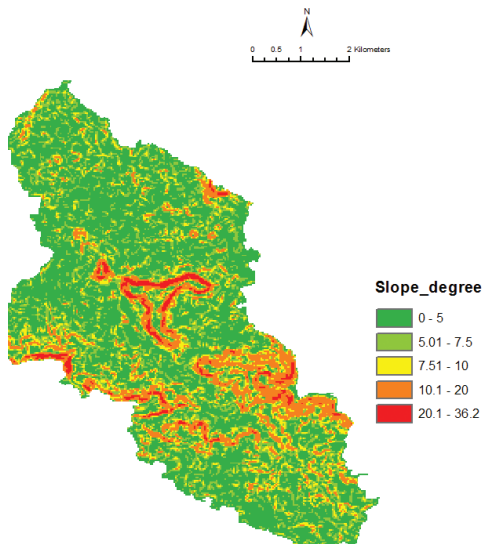


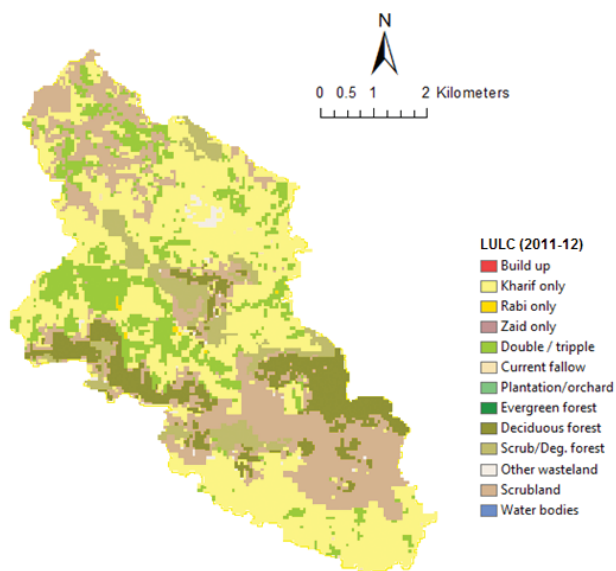
Fig. 1b. Location map of the study area



*Fig. 2 Soil texture of Seethagondi cluster*



*Fig. 3 Slope map of the Seethagondi cluster*



*Fig. 4 Land use land cover map of Seethagondi cluster (2012)*

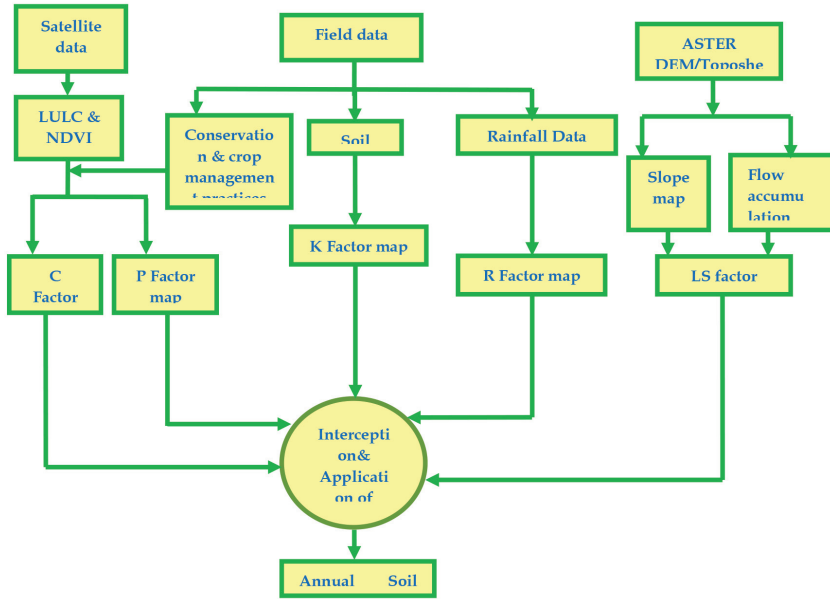


Fig. 5 Flow chart for estimation of soil erosion using RUSLE coupled with GIS

### Erosivity factor

The erosivity factor (R- Factor), expressed in mega joules millimetre per hectare per hour per year ( $\text{MJ mm ha}^{-1} \text{h}^{-1} \text{y}^{-1}$ ) is a measure of the erosive force of a storm or a series of storms to include cumulative erosivity for any time period.  $\text{EI}_{30}$ , the most commonly used rainfall erosivity index, is the product of total kinetic energy during a precipitation event (E) and  $I_{30}$ , its maximum 30 minute intensity. The R- Factor was calculated as the average Erosivity Index ( $\text{EI}_{30}$ ) values calculated over a period of 50 years so as to quantify the effect of rainfall impact associated with precipitation events. The equation for R-factor based on long term daily rainfall intensity derived by Rao and Bharathi for the dryland region (Hayathnagar Research Farm, CRIDA) was used. The daily rainfall grid data could be used for deriving the R\_factor as per the procedure described below (Rejani *et al.*, 2016).

$$R = \frac{\sum_{i=1}^n \sum_{j=1}^m \text{EI}_{30}}{n} \quad 1000/200.6 \quad (2)$$

where R= average annual erosivity index ( $\text{MJ mm ha}^{-1} \text{h}^{-1} \text{y}^{-1}$ ); i= number of years; j= number of days per year;

$\text{EI}_{30}$  = erosivity index corresponding to maximum 30 minute intensity precipitation (hundreds  $\text{t cm ha}^{-1} \text{h}^{-1}$ )

$$\text{EI}_{1440} = 3.856 \text{PI}_{1440} - 0.0048 \quad (R^2=0.83) \quad (3)$$

where,  $\text{EI}_{1440}$  = erosivity index per day (hundreds  $\text{t cm ha}^{-1} \text{h}^{-1}$ )

$$(R^2= 0.89) \quad (4)$$

---

where,  $PI_{1440}$  = daily precipitation index,  $cm^2h^{-1}$  (5)

where daily rainfall is in cm.

The daily R value obtained was converted to monthly and annual values. Then mean annual erosivity was derived.

### Soil erodibility factor

The soil erodibility factor (K Factor) was determined based on the soil type and it reflects the physical and chemical properties of the soil.

### Slope Length Factor (LS factor)

The LS factor is dimensionless and it expresses the effects of topography on soil erosion and is the product of slope length (L) and steepness (S) (Fig.6). The LS factor was derived in this study using Eqn. 6,

$$LS = \left| \frac{\text{Flow accumulation} * \text{cell value}}{22.1} \right|^m (0.065 + 0.045s + 0.0065s^2) \quad (6)$$

where s = slope of the DEM in degrees and m = constant depending on the slope (Sahoo *et al.* 2005)

For slopes of  $DEM \leq 3$ ,  $m = 0.3$

slopes  $>3$  and  $<5$ ,  $m = 0.4$

slopes  $\geq 5$ ,  $m = 0.5$

The values upto  $n=0.6$ ,  $m= 1.3$  gives consistent result with the RUSLE LS factor for slope lengths  $< 100$  m and slope angles  $< 14^\circ$  (Moore and Wilson 1992). In the present study, the values of m ranged from 0.3 to 0.5.

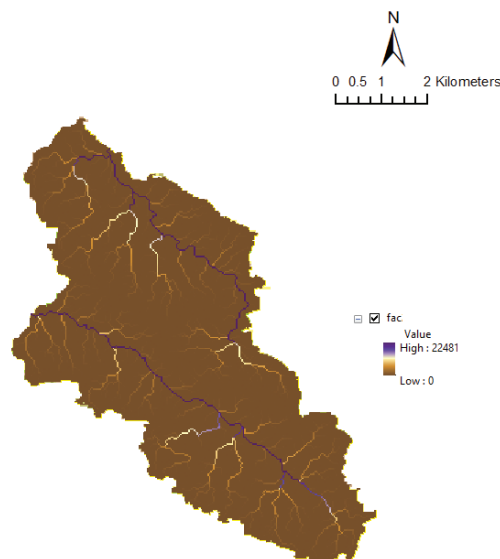


Fig.6 Flow accumulation map of Seethagondi



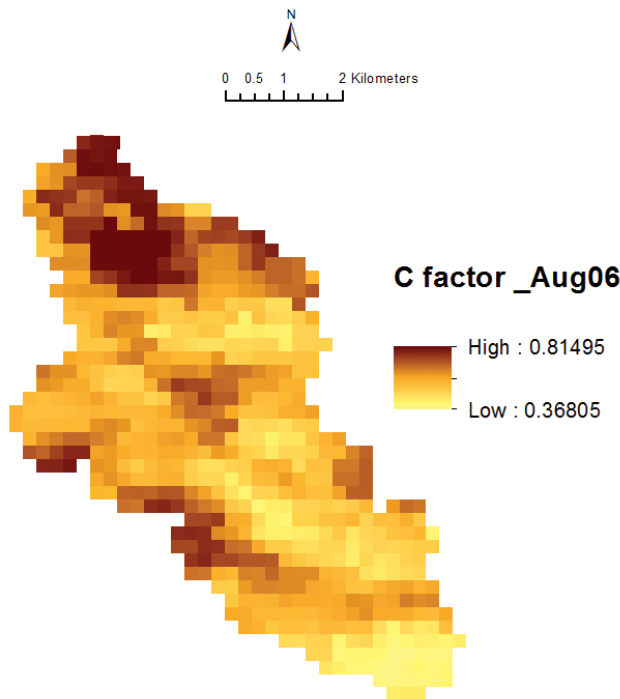
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### Cover Management Factor (C)

C factor is the ratio of soil loss from land with specified cover and management to that from continuous bare fallow soil with same soil, slope and rainfall conditions. C factor was estimated using the methodology (Van der Knijff *et al.* 2000) (Fig.7).

$$C = \exp\left(-\alpha \frac{NDVI}{\beta - NDVI}\right)$$

where,  $\alpha$  and  $\beta$  are the parameters that determine the shape of the NDVI-C curve. The 16-daily NDVI composites were averaged into monthly images to make monthly estimates of C factors.  $\alpha = 2$  and  $\beta = 1$  gives reasonable results (Van der Knijff *et al.* 2000). MODIS NDVI of 16 days interval was used for deriving the C factors.



*Fig.7 Spatial variation of C factor derived from NDVI (August 2006) in the cluster*

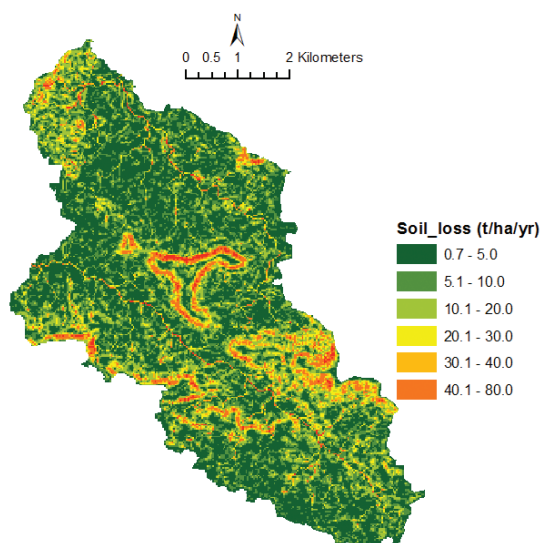
### Conservation practice factor (P)

The conservation practice factor (P-factor) reflects the impact of support practices on soil loss like up and down slope tillage, contour cultivation, strip cropping etc. P-factor map was derived from the land use/land cover map and the support practices followed in the watershed (Reddy *et al.* 2005). The values of P-factor ranged from 0.03 to 1.00 and the soil conservation methods followed in the study area include contour cultivation, field bunding, terracing etc (Reddy *et al.* 2005).

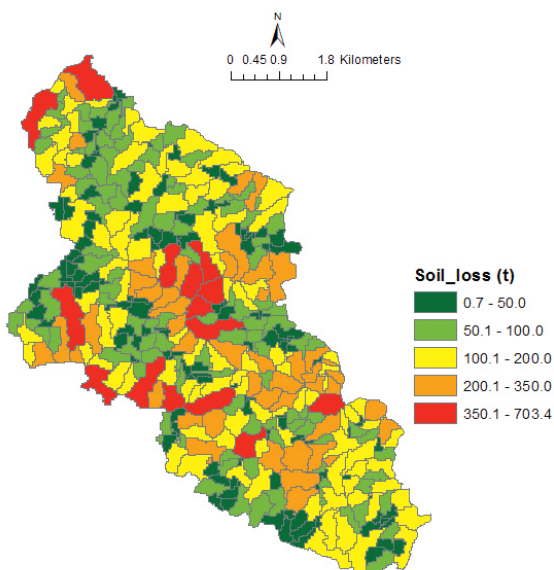
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### Estimation of runoff using RUSLE

The different thematic layers as shown in Flow chart (Fig.5) were intercepted in GIS and RUSLE was applied for obtaining the spatial variation of runoff as shown in Fig.8a. The spatial runoff values were dissolved for the catchments generated in GIS to obtain the soil loss catchment wise (Fig.8b).



*Fig. 8a Spatial variation of annual soil loss in the cluster*



*Fig.8b Spatial distribution of soil loss catchment wise in the cluster*

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## Location specific planning of soil and water conservation interventions based on runoff

The potential sites for different water harvesting structures were planned in three stages as described in flow chart (Fig.9) (Rejani *et al.*, 2017).

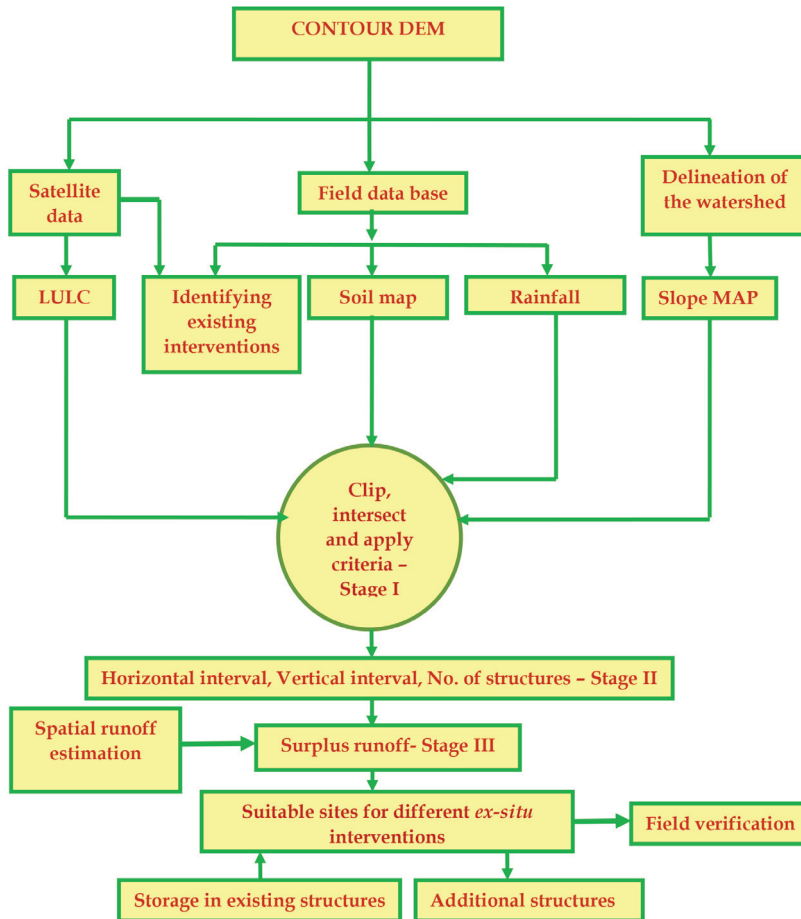


Fig.9. Flow chart depicting the steps for planning water harvesting structures

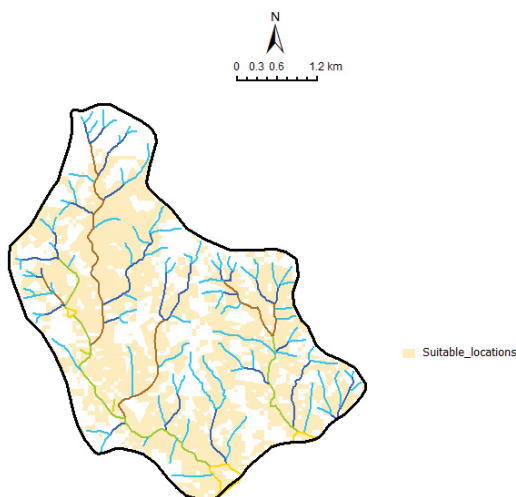
### Stage I: Site suitability

Location specific identification of suitable sites with the aid of GIS involves the application of a set of primary criteria such as soil, climatic, topographic and hydrologic parameters. In the present study, a set of soil and water conservation interventions like rock fill dams, minor percolation tanks, ponds and check dams were suggested for the watershed taking into account of the watershed characteristics and aforesaid parameters. The guidelines presented in Table 2 were followed at Stage I for the planning of suitable sites for the location specific interventions (Fig.10a).

**Table 2. Preliminary site selection criteria for the planning of various soil and water conservation structures**

Structure	Slope (%)	Permeability	Runoff coefficient	Stream order	Watershed area (ha)	Soil type	Rainfall (mm)
Farm ponds (Shrub land)	0-5 <sup>(a &amp; b)</sup>	Low <sup>(a &amp; b)</sup>	Medium/high <sup>(a &amp; b)</sup>	1-2 <sup>(a &amp; b)</sup>	1-2 <sup>(a &amp; b)</sup>	Clay, sandy clay loam <sup>(b)</sup>	>500
Check dams (scrubs/ trees/ river bed)	<15 <sup>(a &amp; b)</sup>	Low <sup>(a &amp; b)</sup>	Medium/high <sup>(a &amp; b)</sup>	3-4 <sup>(a &amp; b)</sup>	25 <sup>(a &amp; b)</sup>	Clay, sandy clay loam <sup>(b)</sup>	>700
Check dams (crop land)	<=3 <sup>(c)</sup>	Low <sup>(a &amp; b)</sup>	Medium/high <sup>(a &amp; b)</sup>	3 <sup>(c)</sup>	25 <sup>(c)</sup>	Clay, sandy clay loam <sup>(b)</sup>	>700
Percolation tanks (scrub land)	<10 <sup>(a &amp; b)</sup>	High <sup>(a &amp; b)</sup>	Low <sup>(a &amp; b)</sup>	1-4 <sup>(a &amp; b)</sup>	25-40 <sup>(a &amp; b)</sup>	Light sandy soil	>700
Percolation tanks (crop land)	<=3 <sup>(c)</sup>	High <sup>(c)</sup>	Low <sup>(a &amp; b)</sup>	1-4 <sup>(a &amp; b)</sup>	25-40 <sup>(a &amp; b)</sup>	Light sandy soil	>700

(Source : <sup>a</sup> Ramakrishnan et al., 2008 & 2009; <sup>b</sup> Kadam et al., 2012; <sup>c</sup> Shanwad et al., 2011; <sup>d</sup> Pauw et al., 2008; <sup>e</sup> Justine et al., 1997)



*Fig.10a Suitable locations for different soil and water conservation interventions at Stage I*

## Stage II: Determination of optimum number of structures

The precise locations and optimum number of structures were determined at Stage II based on the slope, vertical interval, horizontal interval (Fig.10b&c).

Singh *et al.*, 1997 reported Cox's formula for calculation of vertical interval.

$$V = (X+Y) * 0.3 \quad (1)$$

where VI = vertical interval; X = rainfall factor; S = slope percentage and Y = infiltration and crop cover factor. The selected study area has moderate rainfall and hence the rainfall factor (X) was selected as 0.6 and infiltration and crop cover factor (Y) as 2.0.

The optimum number of structures (NS) in drainage lines of micro watersheds was determined using methodology suggested by Rao (2003) at CRIDA. For constructing soil and water conservation structures, at least 20 to 30 m length of flat areas are needed depending upon the size of the structures.

$$NS = \frac{(L - 20)}{HI} + 1 \quad (2)$$

where NS= number of structures; L = length of drainage channel (m); HI=horizontal interval (m)

$$HI = \frac{VI}{S} * 100 \quad (3)$$

LENGTH	DRAIN_	DRAIN	CODE	DESCRIPTIO	slop	Shape_Le	VI	HI	NS
134.6654	8	201	201	FIRST ORDER	1	18.021231	0.78	78	0
168.6806	9	202	202	SECOND ORD	1	5.56264	0.78	78	0
168.6806	9	202	202	SECOND ORD	2	22.288195	0.96	48	1
168.6806	9	202	202	SECOND ORD	0	1.295709	0.6	0	0
168.6806	9	202	202	SECOND ORD	2	0.429745	0.96	48	0
168.6806	9	202	202	SECOND ORD	0	24.141322	0.6	0	0
168.6806	9	202	202	SECOND ORD	1	49.307576	0.78	78	1
168.6806	9	202	202	SECOND ORD	3	34.951031	1.14	38	1
168.6806	9	202	202	SECOND ORD	2	30.704375	0.96	48	1
112.979	10	201	201	FIRST ORDER	10	5.846435	2.4	24	0
112.979	10	201	201	FIRST ORDER	7	21.922955	1.86	26.5714	1
112.979	10	201	201	FIRST ORDER	5	21.922955	1.5	30	1
112.979	10	201	201	FIRST ORDER	3	63.286844	1.14	38	2
336.5796	11	202	202	SECOND ORD	4	1.526948	1.32	33	0
336.5796	11	202	202	SECOND ORD	6	2.536427	1.68	28	0
336.5796	11	202	202	SECOND ORD	4	23.394444	1.32	33	1
336.5796	11	202	202	SECOND ORD	3	24.647716	1.14	38	1
336.5796	11	202	202	SECOND ORD	2	23.679294	0.96	48	1
336.5796	11	202	202	SECOND ORD	2	51.308875	0.96	48	2
336.5796	11	202	202	SECOND ORD	4	5.012799	1.32	33	0
336.5796	11	202	202	SECOND ORD	3	23.575265	1.14	38	1

Fig.10b Optimum number of structures (NS) determined at Stage II



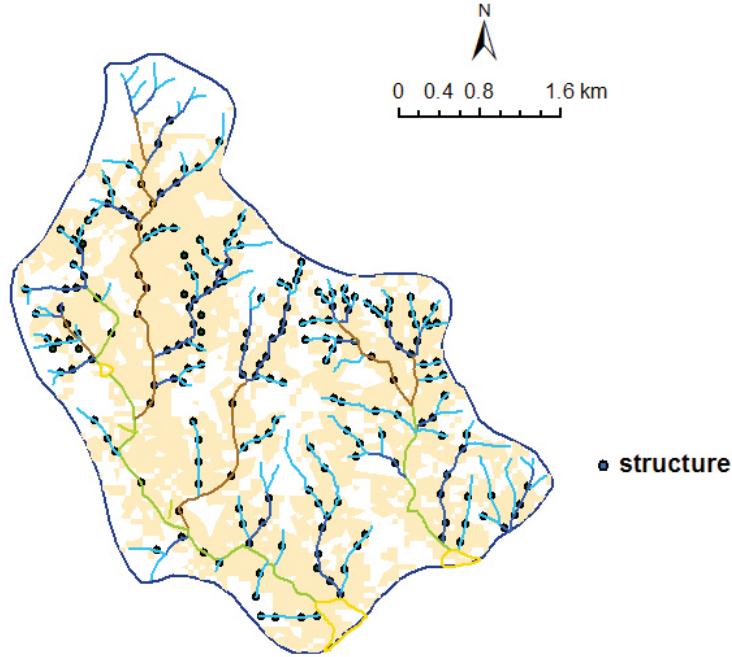


Fig. 10c Potential sites for various ex-situ interventions for Goparajpalli at Stage II

### Stage III: Estimation of surplus runoff and determination of potential sites for structures

In semi-arid regions, runoff potential availability and its temporal variability were considered as alarming factors. Hence, the final locations and number of structures were optimized based on the spatial availability of surplus runoff after *in-situ* soil moisture conservation (Fig.10d-e). The SCS CN method (SCS, 1972) was used for predicting daily runoff (Rejani *et al.* 2015a).

#### Estimation of runoff using SCS-CN method

The contours from SOI toposheet (1:25000) was digitized and DEM was generated from contours. The slope map was derived from DEM using ARCGIS 10. These thematic layers were clipped using the watershed boundary. Soil and LULC data was intersected to generate new polygons associated with soil type and LULC. The runoff was estimated using the SCS CN method given below.

The SCS-CN method (SCS 1972) is an empirical equation predicting runoff from rainfall, using a shape parameter S based on soil, vegetation, land use, and soil moisture prior to a rainfall event

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \text{ for } P > 0.2 S \quad (1)$$

$$Q = 0 \text{ for } P \leq 0.2 S \quad (2)$$

---

where P = total precipitation (mm); Q = surface runoff (mm); and S = potential maximum retention or infiltration (mm). The value of S is given as

$$S = \frac{25400}{CN} - 254 \quad (3)$$

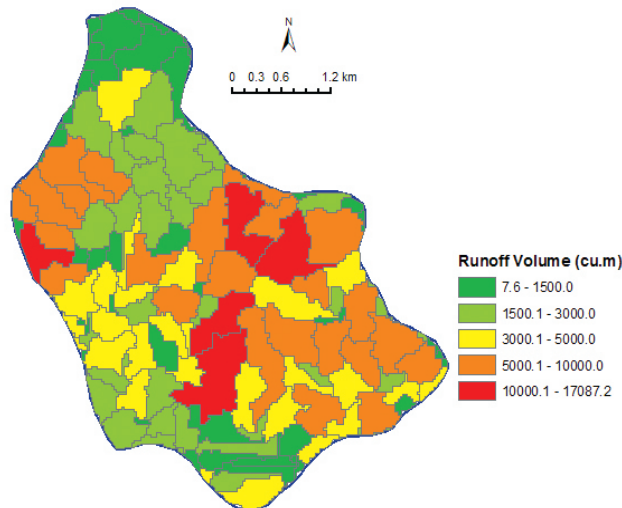
The potential maximum retention storage (S) is related to a curve number (CN), which is a function of land use, land treatments, soil type and antecedent moisture condition of the area. Curve number is dimensionless and its value varies from 0 to 100. It can be obtained from standard tables, however, CN estimation based on real data from local or nearby similar watersheds was used. The potential maximum retention storage (S) is related to a curve number (CN), which is a function of land use, land treatments, soil type and antecedent moisture condition of the area. Curve number is dimensionless and its value varies from 0 to 100. It can be obtained from standard tables, however, CN estimation based on real data from local or nearby similar watersheds was used. The daily runoff depends on the daily rainfall, antecedent moisture condition (AMC), soil properties, land use land cover and slope of the land. The entire area was classified in terms of areas under crops, current fallow, other waste land and scrub land using LULC map. About 90% of the area was characterized by clayey soil and remaining by gravelly loam textured soil (Fig. 2).

Based on soil characteristics, such as infiltration characteristics, depth and texture of the soil profile, the soils were classified into four major hydrologic groups, namely, A (low runoff potential), B (moderately low runoff potential), C (moderately high runoff potential) and D (high runoff potential) (Tripathi and Singh, 1993).

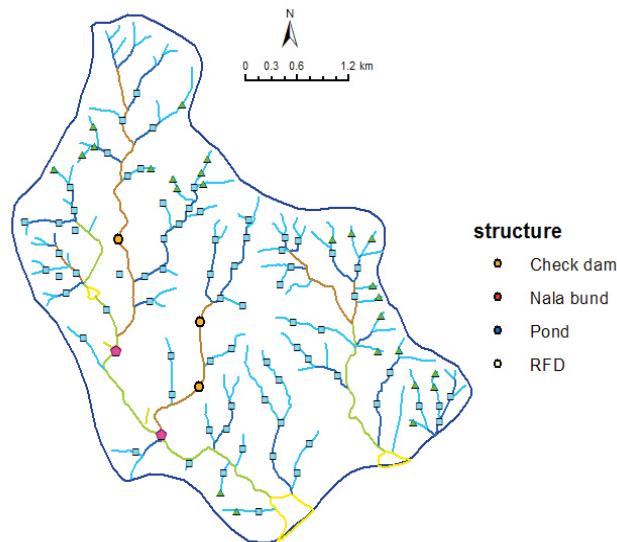
The three levels of antecedent moisture condition (AMC) used were AMC I (low runoff potential; soils are dry; 5 day antecedent rainfall < 35 mm), AMC II (average condition; 52.5 mm > 5 day antecedent rainfall > 35 mm) and AMC III (high runoff potential; soil is saturated; 5 day antecedent rainfall > 52.5 mm) (Kadam *et al.*, 2012). Hence, the different thematic layers were prepared in ARCGIS, intercepted and corresponding curve number values corresponding to three AMC conditions namely, CN2, CN3 and CN1 were assigned for each new polygon and the runoff was estimated spatially and temporally. The daily runoff corresponding to different land use land cover conditions were estimated and annual runoff was derived spatially.

The annual and average annual runoff potentials were determined from daily runoff values. The spatial distribution of average annual runoff (mm) was converted to runoff volume by dissolving it using the catchments derived using the Hydro tool (Fig. 10d). Then the surplus runoff potential was estimated from the total runoff volume by deducting the *in-situ* soil moisture conserved and storage in the existing structures in a normal year. Subsequently, the potential sites were determined based on the surplus runoff potential available after *in-situ* moisture conservation and the locations for various structures identified at Stage II was modified at Stage III (Fig. 10e).

The suitability map for potential locations identified at Stage III was converted to .kml file, exported to Google Earth and validated with the locations of existing structures by visual interpretation. The ground truth pertaining to location of existing structures (latitudes and longitudes) was collected during the survey and was exported to GIS for further validation and planning for additional structures. The additional structures needed were planned after deducting the storage of runoff in the existing structures.



*Fig. 10d Surplus runoff potential available after in-situ water conservation in the watershed*



*Fig. 10e Potential sites determined with the surplus runoff potential available after in-situ moisture conservation (normal year) (Stage III)*

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## Conclusions

GIS is very useful for estimating runoff and soil loss spatially from watersheds or large catchments. For finding the suitable locations for different *in-situ* and *ex-situ* interventions, different thematic layers were integrated in GIS and the set of criteria was applied in three stages. The specific locations and number of structures was determined based on preliminary criteria, slope of the land, vertical interval and horizontal interval required between structures. Since, semi-arid rainfed regions have limitations in the runoff potential availability; these locations were further optimized based on the surplus runoff available after *in-situ* water conservation. This methodology is less time consuming, more precise and can be utilized for the planning of watersheds or even large catchments.

## References

- Justine Anschütz, Antoinette Kome, Marc Nederlof, Rob de Neef. and Ton van de Ven. 1997. Water harvesting and soil moisture retention. Agrodok 13. Stoas Digigrafi Printers, Wageningen, the Netherlands. 95pp.
- Kadam, A.K., Kale, S.S., Pande, N.N., Pawar, N.J. and Sankhua, R.N. 2012. Identifying Potential Rainwater Harvesting Sites of a Semi-arid, Basaltic Region of Western India, Using SCS CN Method. *Water Resources Management*, 26: 2537–2554.
- Moore and Wilson, J.P. 1992. Length slope factor for the revised universal soil loss equation: simplified method of solution, *Journal of Soil and Water Conservation*, 47(4), 423–428.
- Nohara, D. 2006. Impact of climate change on river discharge projected by multimodel ensemble. *Journal of Hydrometeorology*, 7(5):1076–89.
- Patil, J.P., Sarangi, A., Singh, O.P., Singh, A.K. and Ahmad, T., 2008. Development of a GIS interface for estimation of runoff from watersheds. *Water Resources Management*, 22(9), pp.1221-1239.
- Pauw, E.De, Oweis, T. and Youssef, J. 2008. Integrating Expert Knowledge in GIS to locate biophysical potential for water harvesting: Methodology and a case study for Syria. ICARDA, Aleppo, Syria. 59 pp.
- Ramakrishnan, D., Bandyopadhyay, A. and Kusuma, K.N. 2009. SCS CN and GIS based approach for identifying potential water harvesting sites in the Kali Watershed, Mahi River Basin, India. *Journal of Earth Systems Science*, 118 (4): 355–368.
- Ramakrishnan, D., Durga Rao, K.H.V. and Tiwari, K.C. 2008. Delineation of potential sites for water harvesting structures through remote sensing and GIS techniques: a case study of Kali watershed, Gujarat, India. *Geocarto International*, 23:2, 95-108.
- Rao, C.S., Rejani, R., Rao, C.R., Rao, K.V., Osman, M., Reddy, K.S., Kumar, M. and Kumar, P., 2017. Farm ponds for climate-resilient rainfed agriculture. *Current Science*, 112(3), pp.471-477.
- Reddy, R.S., Nalatwadmath, S.K. and Krishnan, P. 2005. Soil Erosion Andhra Pradesh. NBSS Publ. No. 114, NBSS&LUP, Nagpur, India, 76 pp.
- Rejani, R., Rao, K.V., Ch.Srinivasa Rao, Osman,M., Sammi Reddy, K., George, B.A., Pratyusha Kranthi, G.S., Chary, G.R., Swamy, M.V. and Rao, P.J. 2017. Identification of potential rainwater

- 
- harvesting sites for the sustainable management of a semi-arid watershed of Southern India  
*Irrigation and Drainage Journal*, 66(2): 227-237. DOI: 10.1002/ird.2101.
- Rejani, R., Rao, K.V., Osman, M., Chary, G.R., Reddy, K.S. and Rao, C.S. 2015a. Spatial and temporal estimation of runoff in a semi-arid microwatershed of Southern India. *Environmental monitoring and assessment*, 187(8), p.540.
- Rejani, R., Rao, K.V., Osman, M., Chary, G.R., Reddy, K.S. and Rao, C.S. 2015b. Location specific In-situ soil and water conservation interventions for sustainable management of drylands. *Journal of Agrometeorology*, 17(1), p.55.
- Rejani, R., Rao, K.V., Osman, M., Rao, C.S., Reddy, K.S., Chary, G.R. and Samuel, J., 2016. Spatial and temporal estimation of soil loss for the sustainable management of a wet semi-arid watershed cluster. *Environmental monitoring and assessment*, 188(3), pp.1-16.
- Sahoo, A.K., Sarkar, D., Sah, K.D., Maji, A.K. and Dhyani, B.L. 2005. Soil erosion of Orissa, NBSS Publ. No. 126, (48 pp.), NBSS&LUP, Nagpur, India.
- Sanjay, K.J., Jaivir, T. and Vishal, S. 2010. Simulation of runoff and sediment yield for a Himalayan watershed using SWAT model. *Journal of Water Resource and Protection*, 2(3):15
- SCS. 1972. SCS National Engineering Handbook, Section 4. Hydrology, Soil Conservation Service, US Department of Agriculture: Washington, DC.
- Shanwad, U.K., Patil, V.C., Gowda, H.H., Dasog, G.S. and Shashidhar, K.S. 2011. Generation of water resources action plan for Medak Nala Watershed in India using Remote sensing and GIS technologies. *Australian Journal of Basic and Applied Sciences*, 5(11): 2209-2218.
- Singh A. 1974. Selection of structures for soil and water conservation. *Soil Conservation Digest*, 2(2): 49-53.
- Tripathi, R.P. and Singh, H.P. 1993. Watershed management. In soil erosion and conservation, Wiley Eastern Ltd., New Delhi, India, 52-86.
- Van der Knijff, J.M., Jones, R.J.A. and Montanarella, L. 2000. Soil erosion risk assessment in Europe. [http://eusoils.jrc.ec.europa.eu/ESDB\\_Archive/pesera/pesera\\_cd/pdf/ereurnew2.pdf](http://eusoils.jrc.ec.europa.eu/ESDB_Archive/pesera/pesera_cd/pdf/ereurnew2.pdf)
- Yaghoubi, B., Hosseini, S.A. and Nazif, S. 2016. Evaluation of Climate Change Impact on Runoff: A Case Study. *Indian Journal of Science and Technology*, 9(7)1:7.
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# **Watershed Modeling and Management in Sustainable Dryland Farming-Indian Outlook**

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In the changing scenario of agriculture, integrated watershed management has emerged as an option for effective planning and utilization of natural resources. The integrated watershed management is a concept and approach in the sustainable development of land and water resources. Watershed development projects are designed to harmonize the use of water, soil, forest and pasture resources while raising agricultural productivity by conserving moisture in the soil and increasing irrigation through tank and aquifer based water harvesting. Water is both a natural resource and a public good that plays a critical role in a host of environmental processes and economic, social, and political activities. In recent years, watershed management practices that were once praised for their broad benefits to society have become the focus of harsh criticisms for their adverse and unexpected environmental or socioeconomic impacts. Thus, gaining an understanding of how various human activities affect watershed processes, and in turn how the variable nature of the hydrologic cycle affects humans' well-being, is essential for policy makers and watershed managers. Watershed models provide efficient tools for integrated studies of the major hydrological, socioeconomic, and cultural aspects of watersheds. Early watershed modeling efforts were aimed mostly at representing hydrologic processes, but the need for interdisciplinary studies has led to increasing complexity and integration of environmental, social, economic and cultural functions to facilitate a holistic understanding of watersheds and associated human activities. Models help us gain insights into hydrological, ecological, biological, environmental, hydro-geochemical, socioeconomic and cultural aspects of watersheds and thus contribute to systematized understanding of how watershed subsystems function, which is essential to integrated water resources management and decision making.

Soil and water are of paramount importance as a natural resource for public good since these play a critical role in variety of economic, social and environmental activities. The management with these resources optimally, with minimum adverse impact is essential for sustainable development. Watershed is a concept that represents land area usually contains a well-connected stream network, minimal spatial variability in hydrological parameters and well defined outlet or discharge point, where the representative area drains when rainfall occurs. Rainfall interaction with soil resulted into the soil erosion and the safe disposal of runoff without affecting region specific ecology including social and environmental aspect is extremely important. To attend these objectives, watershed management practice is the only option.

Watershed management implies the judicious utilization of land and water resource for increased productivity at minimum depletion of natural resource base. The watershed management concept essentially adopts the soil and water conservation practices in the watershed for implementing resource conservation technologies (RCTs). The major goal of RCT adaptation is to maintain land capability in different aspect such as soil fertility, water resource, drainage, flood protection, reduction in sediment loss, maintaining ecology for increase productivity for human consumption (Srinivasa rao *et. al.*, 2011; Srinivasarao *et. al.*, 2013). The watershed management and multiple use concept, involves integration of various livelihood enterprises to meet the food, fibre, fuel and fodder requirement of the inhabitants. The multiple use management is either resource based or area based. In resource based multiple use represents various alternative use of one or more natural resources e.g. national horticulture mission or bamboo mission; whereas area based represents mixes of products and facilities in a particular area such integrated watershed development program (IWDP) and other watershed development program. Area based watershed management program are more frequent Indian rural settings which forms almost 70% of country population. While planning area based watershed management program it is important to consider the physical, biologic, economic and social factor. Singh (2003) compiled various products obtainable from management of multiple resource of the watershed (Table 1).

Watershed is a manageable hydrological unit and is assumed that the different hydrological parameters do not vary significantly in spatial dimension. The watershed essentially drains the runoff resulted from rainfall to a common point. Thus considering this definition the watershed size can be varied from few hectares to many square kilometers. However, for land water management for agricultural intensification point of view, 500 to 1000 hectares are most suited. Several watershed management program are running in Indian for this size of watershed. However, the new guidelines for implementation of watershed management as suggested by NRAA, National Rainfed Area Authority (2011), encourages to club 10-20 such watershed and follow cluster approach in order to reduce the administrative cost.

**Table 1. Various product obtainable from multiple resource management of watershed (Singh 2003)**

Resource	Products
Water	Irrigation, Municipal and industrial water, recreation
Timber	Timber, pulp, wood, fuel wood, recreation
Forage	Livestock, wildlife, recreation
Wildlife	Consumption, recreation
Minerals	Different minerals

### **Extent of soil erosion problem**

The effects of soil erosion go beyond the loss of fertile land and it has led to increased pollution and sedimentation in streams and rivers, clogging waterways. More than 80% of world's agricultural land suffers from moderate to severe soil erosion (Pimentel and



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Kounang, 1998). The mean annual soil erosion rate on cropland is approx. 30 Mg ha<sup>-1</sup>, while reported values vary from 0.5 to over 400 Mg ha<sup>-1</sup> yr<sup>-1</sup> (Pimentel and Kounang, 1998). Soil erosion rates, caused by water, are highest in agrosystems located in hilly or mountainous regions of Asia, Africa and Southern America, especially in less developed countries. In the hillocks of high rainfall area, erosion can be controlled by planting crops along the contour and by managing land use in such a way that soil disturbing activities should be less during the period of erosive rains. In India, it is estimated that water erosion causes damage on 113.3 million ha threatening the productivity and the fertility of the soil (Tirkey *et al.*, 2013). In order to restore the productivity of the soil and to prevent further damage, planning, conservation and management of the catchments are inevitable. Hence, gauging stations are needed to record the runoff and sediment yield. In cases of ungauged areas, runoff and soil loss estimation methods like SCS curve number method and Revised Universal Soil Loss Equation (RUSLE) can be adopted (Rejani *et al.*, 2014).

### **Status of Groundwater utilization**

The rapid industrialization, population growth, climate change and agricultural activities resulted in over-utilization of the fresh water resources leading to reduction of groundwater level in many parts of India (Kadam *et al.*, 2012). The scarcity of water in India is a well known fact in spite of higher average annual rainfall of 1,170 mm compared to the global average of 800 mm (Jasrotia, 2009). India is the largest user of groundwater for irrigation in the world and the drawn amount of groundwater is estimated to be 210 billion cubic meters/year compared to 105 billion cubic meters in China and 100 billion cubic meters in US (Shankar *et al.*, 2011). According to the 2005-06 Agricultural Census, 60.4 percent of the net irrigated area is irrigated using groundwater. According to the CGWB, 15 percent of the administrative blocks are over-exploited and are growing at a rate of 5.5 percent per annum. The most substantial decline in groundwater level is observed in north western India over a period of 30 years (1980 to 2010). In many parts of Gujarat and Rajasthan, groundwater level fell more than 16 meters (Sheetal Sekhri, 2012). A decline of 1 to 4 meters was observed in states like Telangana and Andhra Pradesh. The depletion of groundwater resources has increased the cost of pumping, caused seawater intrusion in coastal areas and has raised questions about sustainable groundwater supply as well as environmental sustainability (Rejani *et al.*, 2009). Hence, optimal groundwater management and recharging of aquifers are very essential.

### **Watershed development in India**

The government of India has identified the watershed management as a part of approach to improve agricultural production and alleviate poverty in rainfed regions. The watershed management program are implemented in India since the 1970s. These programs majorly aim to restore degraded watersheds in rainfed regions to increase their carrying capacity by rainwater harvesting, reduction in soil erosion and thus improving soil nutrient and carbon content in order to produce higher agricultural yields and other benefits. As the majority of India's rural poor live in these regions and are dependent on natural resources for their livelihoods and sustenance, improvements in agricultural translates into improvement in

human welfare vis a vis improving national food security (Ahmad *et al.*, 2011; GOI, 2011; Kerr, 2002). The major focuses of watershed management program practiced in India are however, on rainfed regions. This is particularly important as these areas represent 60 percent of arable land in India and producing 50% of country's agricultural output that supports 40 percent of the nation's population (Planning Commission, 2012). Despite of these, the rainfed region of the county are characterized by low productivity, fragment land holding, vulnerability due to both geographical and climatic conditions, and also poor land and water management. This results into the lower productivity of rainfed areas in which crop productivity is almost one third of national average. There are several agro-climatic zones of rainfed area at different geographical elevation ranging from sea shore to hill and mountain. The brief historical development in watershed management programs in India is presented in Table 2.

**Table 2. Historical development of watershed management program**

<b>Year</b>	<b>Program/policy/guidelines</b>
1973	Drought prone area program (DPAP)
1977	Desert development program (DDP)
1989	Integrated watershed development program(IWDP); Integrated afforestation and eco development scheme
1991	National watershed development project for rainfed area (NWDPRA)
1993	Indo-German watershed development program.
1999	Watershed development fund
2003	Hariyali guidelines
2005	Mahatma Gandhi national rural employment guarantee scheme (MGNREGS)
2006	National rainfed area authority
2009	Integrated watershed management program
2011	Common guidelines for watershed development.

### **Hydrological modeling for watershed management**

Models representing the hydrological process confined in a watershed are called hydrological modeling of watershed. The various hydrological processes are defined in the series of mathematical equations pertinent to the specific watershed characteristics. These models are mathematical representations of watershed processes and also affected socioeconomic and environmental systems. Thus this become a fundamental and integrated element to alter diverse natural processes. These models help in getting insights on various aspects of watershed. These aspect includes hydrological, ecological, biological, environmental, hydrogeochemical, and socioeconomic aspects of watersheds (Singh and Woolhiser, 2002). These aspect are extremely required to develop system dynamics of specific watershed understand the watershed function (Lund and Ferreira, 1996 Lund and Palmer, 1997), which is essential to integrated water resources management and decision making (Madani and Marino, 2009).

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## The hydrological cycle

The hydrologic cycle is a conceptual model that describes the interaction of underlying different hydrological process among biosphere, atmosphere, lithosphere, and the hydrosphere in which water is the main carrier. Water on earth can be stored in any form reservoirs such as atmosphere, oceans, lakes, rivers, soils, glaciers, snowfields, and groundwater etc. Water moves from one reservoir to another hydrological process like evaporation, condensation, precipitation, deposition, runoff, infiltration, sublimation, transpiration, melting, and groundwater flow. The general structure of hydrological modeling is presented in Fig. 1. The hydrological models mainly attempts water balance modeling of various hydrological components. The relative interaction among various components of hydrologic cycle is described in the Figure 1.

### Types of hydrological model

The different components of hydrologic cycle are represented conceptually in simplified form of hydrological models. These are developed to understand the hydrological process for prediction and estimation of hydrological parameters. The hydrological modeling, essentially a set of mathematical formulae can be classified in to three broad groups.

**Stochastic models or black box models.** These models are developed based on observed data and using mathematical and statistical concepts to link a certain input and model output. The underlying hydrological processes are defined by Location specific coefficients. Commonly used techniques are regression, transfer functions, neural networks (Kumar *et al* 2002 and 2009) and system identification. These models are known as stochastic hydrology models. These models have limited applicability.

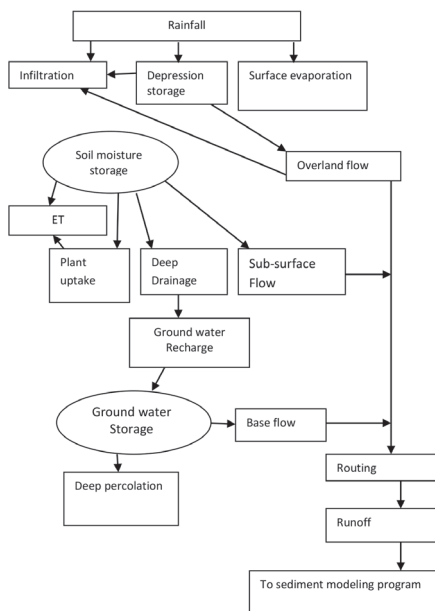


Fig. 1 Flowchart for typical hydrological modeling approach

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**Process-based models.** These models represent the physical processes observed and mathematical relationship are derived based on physical interaction among the factors. Typically, such models contain representations of surface runoff, subsurface flow, evapotranspiration, and channel flow in separately and form as a parameters for water or energy balance and thus are more complicated. These models are also known as deterministic hydrology models. Deterministic hydrology models can be subdivided into single-event models and continuous simulation models.

**Simulation models:** Simulation models consist of surface water models, groundwater models (flow and transport) (Rejani *et al.*, 2008), composite models containing both (surface and groundwater) and agricultural hydro-salinity models. These models utilize simulation and optimization approach. Simulation models take physical parameters and engineered designs or management plans as inputs and generate detailed predictions of outcomes. Simulation is widely applied in the detailed design phase of projects for quantitative performance and impact analysis of a limited number of alternative designs.

### **Synthesis of watershed modeling**

Watershed modeling for management includes development of models to analysis “what if” scenario for various options. In the past, water resource professionals have been developed, attempted and evaluated several hydrological models to solve various watershed management problem, yet watershed management models are still in evolving phase. Since hydrological process involved in watersheds are highly complex and non-linear in nature, there is difficulty in developing model to address watershed problem in terms of approach, application and reliable understanding of the management problem. Initially during 60’s, watershed modeling efforts were limited quantitative computation of individual hydrologic processes (Singh and Woolhiser, 2002). Various components of the hydrologic cycle, such as surface runoff, infiltration, groundwater flow, and evapotranspiration, were modeled separately due to, but a lack of data and computing capability hindered more integrated analysis (Freeze and Harlan, 1969; Chen *et al.*, 1982). Next paradigm shift in watershed management modeling was to develop simulation model to develop decision support system (DSS). These support systems were developed primarily to assess the effect on watershed response to a specific activity and accordingly to suggest the development and management options. The main criteria in these DSS were to select a treatment and its relative effect on runoff and soil loss.

It is extremely important for policy planners and watershed managers to have firsthand understanding and knowledge of how various human activities affects watershed processes and also and to know how the dynamic nature of the hydrologic cycle affects life. Integrated watershed modeling, aims to provide efficient tools for integrated studies of the major physical, socioeconomic, and cultural aspects of watersheds. There is a paradigm shift from rainfall-runoff modeling of watershed to the integrated watershed modeling. However, watershed modeling is still evolving in terms of approach, application, and ability to provide users with a comprehensive and reliable understanding of problems

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at a reasonable cost and within a specified timeframe. Watershed management decision making is a complex process and several factors need to be looked in while balancing biophysical and socio-economical concerns. Now a day the public is actively participating in environmental decisions through public debates, and so there is a need for efficient technology transfer from public agencies to stakeholders is increasing. Application of information technology thus has a profound influence on watershed management over the past decade. Advances in data acquisition through remote sensing, data utilization through geographic information systems (GIS), and data sharing through the Internet have provided watershed managers access to more information for management decisions.

### **Integrated modeling for watershed management**

The integrated model will link biophysical modeling with village scale socio-economic and cultural models (Fig. 2). This approach is necessary to develop a holistic understanding of interactions between land, water, and people. The hydrologic models provide an assessment of the availability of surface and groundwater resources for watershed development and climate scenarios. The crop models simulate yields as well as water use and recharge which feed back into the next season hydrology. Water availability and crop productivity are the main links between the biophysical and socio-economic models (Merritt *et al.*, 2011). This information in addition to survey data detailing access to land, water and common pool resources as well as network and demographic data is input to the socio-economic and cultural models which simulate the response of social and economic indicators for groups differentiated on social (e.g. gender, caste) or economic (e.g. landless, landholders) characteristics or cultural differences (e.g. demographics, status of its social groups (tribes), sectoral shifts). Issues of equity will be assessed by analysing trade-offs within and between villages. Biophysical models can be linked to the socio-economic and cultural models by full integration where the socio-economic and cultural models are dynamically updated with information from scenarios runs from the crop and hydrology models, or the outputs from the biophysical models are used as inputs to the socio-economic and cultural models. The type of linkage depends on the structure of the socio-economic and cultural models, its responsiveness, complexity, scale and linkages with groundwater, surface water and crop models.

### **Socio-economic and cultural models**

Socio-economic and cultural models are generally optimization models for creating alternatives based on selecting values for decision variables that provide the best value of an objective function, subject to a set of mathematical constraints. Some advantages of optimization models are that they can help to screen a large number of potential alternatives, generate new alternatives that otherwise may have been overlooked, and provide an intuitive means of trade-off analysis. Also, optimization results need to be interpreted carefully, as the “optimal” outcomes may be overly optimistic and not achievable in practice (Mirchi *et al.*, 2009).

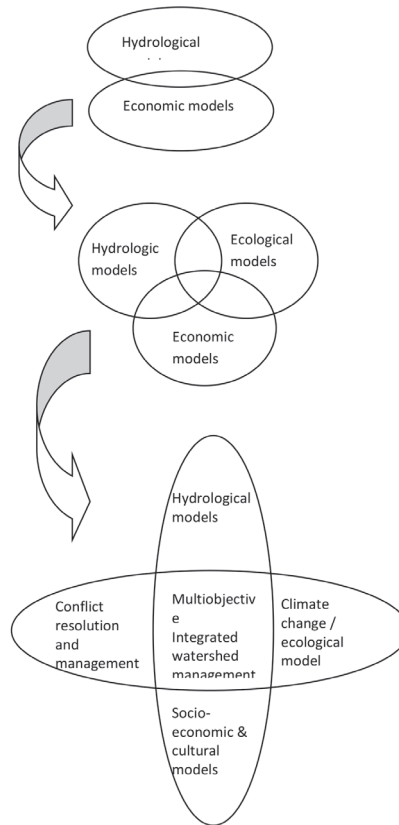


Fig. 2. Evolution of watershed management modeling

These process models have been used in a wide range of studies, including rainfall-runoff prediction, flood mitigation design, water supply development, safety assessment of water infrastructure, land use planning, irrigation planning, hydropower operations, and surface and groundwater quality protection (Carvallo *et al.*, 1998; Hsiao and Chang, 2002)

### Integration of hydrologic and socio- economic watershed models

Integration of hydrologic and socio- economic watershed models form the hydro economic models, often based on optimization methods, possess the advantage of facilitating economic studies by maximizing or minimizing some specified economic objective function subject to a series of constraints. Hydro economic models have been applied to analyze water resources management practices and potential economic and environmental impacts, to address trade-offs and interactions among various stakeholder groups, to evaluate long term drought management and flood mitigation plans, to improve water resources operation policies and strategies, to suggest climate change adaptation strategies, and to improve water quality and quantity for ecosystems (Mirchi *et al.*, 2009; Rejani *et al.*, 2009).

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Multi-objective optimal control model (OCM) for watershed-scale management of ecosystem can be obtained by coupling a semi-distributed hydrologic model, SWAT with a multi-objective optimization algorithm, NSGA-II (Nondominated Sorting Algorithm II) (Maringanti *et al.*, 2009; Bekele and Nicklow, 2007). This model is designed to identify land uses and management practices that could result in improved production of ecosystem services and maximized net gross margin. However, maximizing the economic value of water use serves as the only driver of decisions in hydro-economic models as economic valuation of many social, political and environmental objectives remains difficult (Harou *et al.*, 2009). Integrated modeling of watershed-scale hydrological, environmental, and economic aspects of water use often requires simplified representation of natural processes (Heinz *et al.*, 2007). Thus, water resources management decisions which are solely based on hydro-economic models may not be comprehensive and a holistic model and approach are required for integrated water resources management (Mirchi *et al.*, 2009).

### **Multi-objective decision making models**

Linear and non-linear programming has been the two widely used optimization techniques for efficient planning and management of surface and groundwater systems. The watershed planning and management decisions may consider multiple goals, which may be conflicting. Often it is impossible to aggregate the goals into a single criterion or performance measure in the alternative ranking and selection process (Makowski *et al.* 1996). Thus, multi-objective decision support methods are widely used for water policy planning and evaluation, strategic watershed planning and management (Hajkowicz and Collins, 2007). Many optimization models exist for water management systems but there is a knowledge gap in linking bio-economic objectives with the optimum use of all water resources under conflicting demands. Minimization of risks associated with agricultural production requires accounting for uncertainty involved with climate, environmental policy and markets (Xevi and Khan, 2005).

The complex simulation models and with genetic algorithm-based multi-objective optimization (MO) (Nondominated Sorting Algorithm II, NSGA-II) approach can be used to solve two competing management objectives, such as allowable urban growth and water quality (Dorn and Ranjithan, 2003). Multi-objective optimization model coupled with watershed model (SWAT) can be used for selection and placement of best management practices in watersheds (Bekele *et al.*, 2003). Multiple criteria analysis techniques are used in river basin planning and development (Cai and Rosegrant, 2004), water resources development, land use management, groundwater/ surface water allocation (Vamvakieridou-Lyroudia *et al.*, 2005), flood management (Woodward *et al.*, 2014) and water resources quality. The watershed planning and management objectives lead to conflicts among watershed stakeholders, or interest groups. In many cases, different stakeholder groups share common interests or they may be able to reach compromise (Mirchi *et al.*, 2009). Conflict resolution models essentially seek to promote compromise through holistic understanding of technical, socioeconomic, political, and environmental aspects of the problem (Lund and Palmer, 1997).



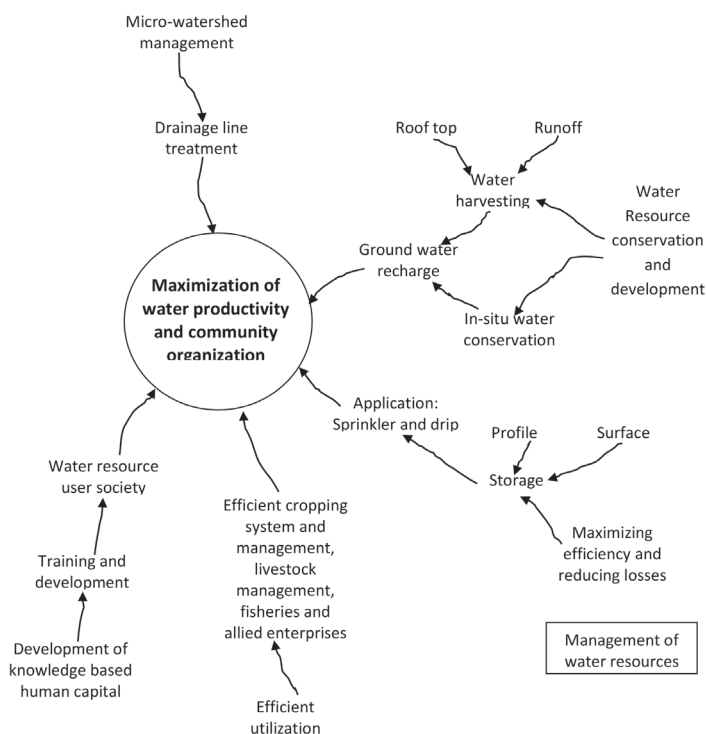
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## Watershed management module

The most important watershed management modules include (1) water resource development and management modules; (2) integrated farming system module. Various processes under these modules are explained in dendrograms shown in figure 3 and 4 respectively.

### Future directions in watershed modeling and development

In spite of the complexity and uncertainty of various watershed processes, many models have been successfully developed and used by modelers and decision makers. The ability to model the hydrologic processes with greater accuracy and resolution, will continue to improve with the use of high resolution remote sensing data, advanced numerical techniques, increased computational capacity, and improvements in GIS and other database management systems. However, there is chances of error of omission and error of commission in mathematical modeling of hydrological processes. Because developing a complex model that cannot be properly calibrated and verified using available data, or developing a model that fails to make proper use of available, high-quality data. Hence, determination of the best suitable watershed management practices for a particular region is complicated due to the variation in socioeconomic, cultural, political, and climatic factors. Therefore, application of integrated models and documentation of the corresponding results are needed, which will help in watershed planning, management, and decision making.



*Fig. 3. Dendrogram depicting various processes of water resource development and management in a watershed*

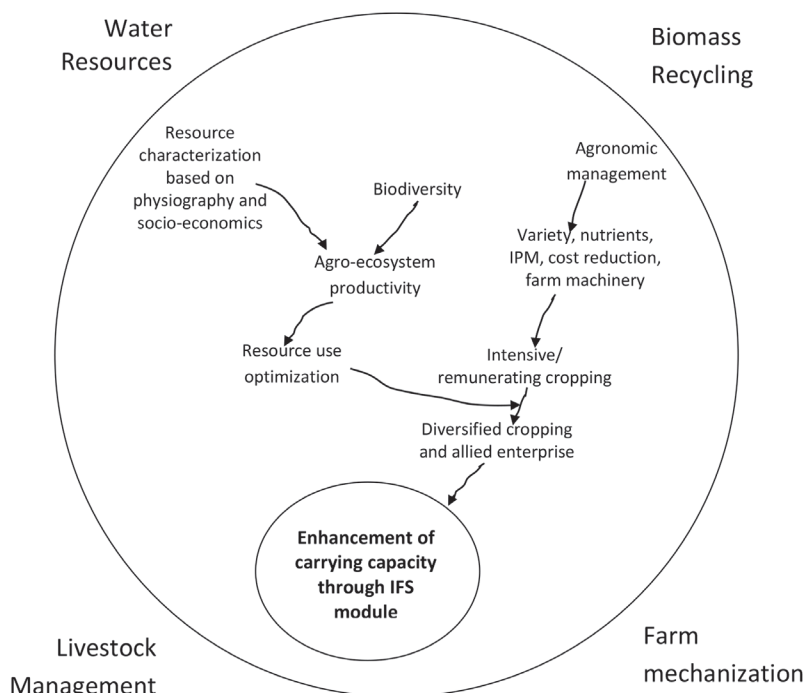


Fig. 4. Dendrogram depicting integration of various activities in enhancement of carrying capacity of watershed through integrated farming system

## Conclusions

Earlier studies showed that unsustainable watershed planning and management can result in environmental disasters as well as socioeconomic problems. Watershed modeling has become a reliable tool for water resources system design, planning, and management at an affordable cost within a reasonable time. The continuous growth in computational capacities, along with other advances in data collection and management, has allowed watershed models to evolve from lumped mode models to physical process models and ultimately to integrated models comprising of hydrological, social, economic, cultural and environmental models with the objective of giving support for decision making. The improvement of the simulation models into integrated models have made promising changes in the watershed modeling.

## Reference

- Ahmad, J., Alam, D. and Haseen, S., 2011. Impact of climate change on agriculture and food security in India. *International Journal of Agriculture, Environment and Biotechnology*. Vol. 4 (2): 129–137.
- Bekele, E.G. and Nicklow, J.W. 2007. Multi-objective optimal control model for watershed management using SWAT and NSGA-II. *World Environmental and Water Resources Congress 2007*: pp. 1-10. doi: 10.1061/40927(243)171

- 
- Bekele, E.G., Lian, Y. and Demissie, M. 2011. Development and application of coupled optimization-watershed models for selection and placement of best management practices in the mackinaw river watershed, Contract Report 2011-04, The Nature Conservancy, Illinois State Water Survey.
- Cai, X. and Rosegrant, M.W. 2004. Optional water development strategies for the Yellow River basin: Balancing agricultural and ecological water demands. *Water Resources Research*, 40(4), doi:10.1029/2003WR002488.
- Carvalho, H.O., Holzapfel, E.A., Lopez, M.A. and Marino, M.A. 1998. Irrigated cropping optimization. *Journal of Irrigation and Drainage Engineering*, ASCE, 124(2): 67-72.
- Chen, C.W., Dean, J.D., Gherini, S.A. & Goldstein, R.A. 1982. Acid rain model hydrologic module. *Journal of Environmental Engineering*, ASCE 108 (E3), 455-472.
- Dorn, J.L. and Ranjithan, S.R. 2003. Evolutionary multi objective optimization in watershed water quality management. *Evolutionary Multi-Criterion Optimization. Lecture Notes in Computer Science*, Volume 2632, 2003, pp 692-706.
- Freeze, R.A. and Harlan, R.L. 1969. Blueprint for a physically-based, digitally-simulated hydrologic response model *Journal of Hydrology*, 9, 237-258
- Government of India, 2011. Common guidelines for watershed development projects – 2008 (Revised edition 2011). National Rainfed Area Authority, Planning Commission. New Delhi, India.
- Hajkowicz, S. and Collins, K. 2007. A review of multiple criteria analysis for water resources planning and management, *Water Resources Management*, 21, 1553-1566.
- Harou, J.J., Pulido-Velazquez, M.A., Rosenberg, D.E., Medellin-Azuara, J., Lund, J.R. and Howitt, R. 2009. Hydro-economic models: concepts, design, applications and future prospects, *Journal of Hydrology*, 375, 334-350.
- Heinz, I., Pulido-Velasquez, M., Lund, J. and Andreu, J. 2007. Hydro-economic modeling in river basin management: implications and applications for the European Water Framework Directive, *Water Resources Management*, 21, 1103-1125.
- Hsiao, C.T. and Chang, L.C. 2002. Dynamic optimal groundwater management with inclusion of fixed costs. *Journal of Water Resources Planning and Management*, 128(1): 57-65.
- Jasrotia, A.S., Majhi, A. and Singh, S. 2009. Water balance approach for rainwater harvesting using remote sensing and GIS techniques, Jammu Himalaya, India, *Water Resources Management*, 23: 3035–3055.
- Kadam, A.K., Kale, S.S., Pande, N.N., Pawar, N.J. and Sankhua, R.N. 2012. Identifying potential rainwater harvesting sites of a semi-arid, basaltic region of western india, using SCS-CN method, *Water Resources Management*, 26:2537–2554.
- Kerr, J., Pangare, G. and Pangare, V.L., 2002. Watershed development projects in India: An evaluation, International Food Policy Research Institute, Research Report 127. Washington DC.
- Kumar, M., Raghuwanshi, N.S., Singh, R., Wallander, W.W., and Pruitt, W.O. 2002. Evapotranspiration estimation using artificial neural network, *Journal of Irrigation and Drainage Engineering*, ASCE 128(4): 224:233 pp.
-

- 
- Kumar, M, Raghuwanshi, N.S. and Singh, R. 2009. Development and validation of generalized artificial neural network (GANN) model for evapotranspiration estimation, *Journal of Hydrologic Engineering*, ASCE, 44(2):131-140pp.
- Lund, J.R. and Ferreira, I. 1996. Operating rule optimization for Missouri River reservoir system, *Journal of Water Resources Planning and Management*, 122(4), 287-295.
- Lund, J.R. and Palmer, R.N. 1997. Water resource system modeling for conflict resolution, *Water Resources Update*, 108, 70-82.
- Madani, K. and Mariño, M.A. 2009. System dynamics analysis for managing Iran's Zayandeh-Rud river basin, *Water Resources Management*, 23(11), 2163-2187, doi: 10.1007/s11269-008-9376-z.
- Makowski, M., Somlyódy, L. and Watkins, D. 1996. Multiple criteria analysis for water quality management in the Nitra Basin, *Water Resources Bulletin*, 32, 937-947.
- Maringanti, C., Chaubey, I. and Popp, J. 2009, Development of a multiobjective optimization tool for the selection and placement of best management practices for nonpoint source pollution control, *Water Resour. Res.*, 45, W06406, doi:10.1029/2008WR007094.
- Merritt, W.S., Reddy, V.R., Rao, K.V., Pavelic, P., Ahmed, S., Ranjan, R., Croke B.F.W. and Syme, G.J. 2011. Integrated modelling for understanding watershed development impacts on social and biophysical systems, 19th International Congress on Modelling and Simulation, Perth, Australia, 12-16 December 2011. Mirchi, A., Watkins Jr., D., and Madani, K. 2009. Modeling for watershed planning, management and decision making, Chapter 6. In: *Watersheds: Management, Restoration and Environment* (Editor: Jeremy C. Vaughn), BN: 978-1-61668-667-3.
- National Rainfed Area Authority. 2011. Common guidelines for watershed development projects-2008, Revised editions-2011, National Rainfed Area Authority, Planning Commission, 2011.
- Pimentel, D. and Kounang, N. 1998. Ecology of soil erosion in ecosystems, *Ecosystems* 1: 416-246.
- Rejani, R., Rao, K.V., Prathyusha Kranthi, G.S., Osman, M. and Pushpanjali. 2014. SRTM and ASTER DEM applications for watershed delineation and runoff estimation – A case study from Odisha and Kerala. *Compendium of the National Seminar on 'Spatial Technologies for Watershed Planning'*, Kerala State Land Use Board, Kerala: pp: 27-39.
- Rejani, R., Jha, M.K. and Panda, S.N. 2009. Simulation-optimization modelling for sustainable groundwater management in a coastal basin of Orissa, India, *Water Resources Management*, 23: 235-263.
- Rejani, R., Jha, M.K., Panda, S.N. and Mull, R. 2008. Simulation modeling for efficient groundwater management in Balasore coastal basin, India. *Water Resources Management*, Vol.22 (1): 23-50.
- Shankar, P.V., Kulkarni, H., and Krishnan, S. 2011. India's groundwater challenge and the way forward, *Economic and Political Weekly*, 46(2).
- Sheetal Sekhri. 2012. Sustaining groundwater: role of policy reforms in promoting conservation in India, Report of Indian Policy forum 2012. India International Centre, New Delhi.
-

- 
- Singh, R.V. 2003. Watershed planning and management, Second edition, Yash publishing home, 1-10 pp
- Singh, V.P. & Woolhiser, D.A. 2002. Mathematical modeling of watershed hydrology, *Journal of Hydrologic Engineering*, Vol. 7, No. 4, July/August 2002, pp. 270-292
- Srinivasarao, Ch. , Venkateswarlu, B., Rattan Lal, Singh, A.K., and Sumanta Kundu. 2013. Sustainable management of soils of dryland ecosystems of india for enhancing agronomic productivity and sequestering carbon, In Donald L. Sparks, editor. *Advances in Agronomy*. Academic Press Burlington, 2013a; 121, pp. 253-329. ISBN: 978-0-12-407685-3.
- Srinivasarao, Ch., Venkateswarlu, B., Srinivas, K., Kundu, S. and Singh, A.K. 2011. Soil carbon sequestration for climate change mitigation and food security. In *Soil carbon sequestration for climate change mitigation and food security*. Central Research Institute for Dryland Agriculture, Hyderabad, India; p. 372.
- Tirkey, A.S., Pandey, A.C., and Nathawat, M.S. 2013. Use of satellite data, GIS and RUSLE for estimation of average annual soil loss in Daltonganj watershed of Jharkhand (India), *Journal of Remote Sensing Technology*, 1(1): 20-30 .
- Vamvakieridou-Lyroudia, L., Walters, G., and Savic, D. 2005. Fuzzy multiobjective optimization of water distribution networks. *Journal of Water Resources Planning and Management*, 131(6), 467–476.
- Woodward, M., Gouldby, B., Kapelan, Z., and Hames, D. 2014. Multiobjective optimization for improved management of flood risk. *Journal of Water Resources Planning and Management*, 140(2), 201–215.
- Xevi, E. and Khan, S. 2005. A multi-objective optimisation approach to water management, *Journal of Environmental Management*, 7(4): 269–277.

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# Gender Mainstreaming in Natural Resources Management

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Rainfed areas in India constitute 55 per cent of the net sown area of the country and home to two- thirds of livestock and 40 percent of human population (NRAA, 2012). 170 m.ha land in India is classified as degraded land, the majority falling in undulating semi arid areas where rainfed farming is practiced (Rai & Singh 2008). Rainfed agriculture is a complex, diverse and risk prone agriculture. It suffers inadequate and erratic rainfall leading to low productivity. Rainfed areas usually support small and marginal farmers, pastoralists and however, poverty in these areas is predominant. Proper management and efficient utilization of resources is key to rainfed areas development. Timeliness of operations, utilization of *insitu* moisture are found to be essential cost effective management practices. Related technologies generated such as conservation tillage, mulch, residue incorporation, precision and timely seeding, weeding control, plant protection, timely harvesting and post harvest operations are effective in moisture conservation adopted by the rainfed farmers (Mayande 2002). Technology adoption, however, vary with different farmers categories and socio economic status.

Drylands pose different challenges for rural men and women because of gender based roles, relations and responsibilities, uneven access and control of resources and different opportunities and constraints. Agricultural related programmes, policies often fail to recognize women's particular needs and crucial contribution in the use and management of dryland resources (FAO, 2009) Several international agreements, such as the Agenda 21(1992), the Beijing platform of Action (1995), the framework convention on climate change (1992) and its Kyoto Protocol (1997) and international convention to combat Desertification (1999) have been adopted by the international community to consider women and men's equal participation and benefit from development initiatives, such transformations would also ensure effectiveness of strategies aimed at sustainable development of dryland regions.

## **Challenges in management of natural resources**

**Land:** The scope to expand the area available for cultivation as the demand for industrialization, urbanization, housing and infrastructure is forcing conversion of agricultural land to non – agricultural uses is limited. With an increasing pressure of population and a decreasing per capita availability of cultivable land, there is a need to enhance cropping intensity without compromising land productivity. After independence till the 1970s, Indian agriculture was characterized by intensive agriculture practices in favorable ecologies through an integrated use of HYVs, irrigation, fertilizer, pesticide

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use and technologies with mining of natural resources to meet the food security needs. Since the 1980s, the adverse effects and limitations of the green revolution technologies were realized and the emphasis shifted to appropriate/alternative and Sustainable land use systems and to improving the efficiency of resources and inputs.

**Soil and water:** As land resources are stagnant, an increase in food production has to come from increase in productivity. The quality of Indian soils is gradually deteriorating at the farm and eco-system level. The major threats to soil quality come from a loss of organic carbon, erosion, nutrient imbalance, compaction, salinization, water-logging, decline in soil bio-diversity, urbanization, contamination with heavy metals and pesticides and from an adverse impact of climate change.

**Challenges:** The concerns for future trends and scenarios should centre on enhanced water efficiency, sustainability of irrigated eco-systems, livelihood and intergenerational equity. Several parts of India are already facing water shortages and the problem will become acute by 2050 with nearly all the estimated available water put to use as a result of increasing population and food demand. Currently, reuse and recycling of wastewater is not practiced on a large scale in India, and there is a considerable scope to use this alternative. ‘Reuse’ applies to wastewaters that are discharged from municipalities, industries and irrigation and then withdrawn by users other than the dischargers. Studies on the likely impacts of increased climate variability and climate change on the water resources have been limited. Under a changed climatic scenario, a number of chain events like the melting of glaciers, sea-level rise, submergence of islands and coastal areas, and deviant rainfall patterns, are likely to occur. Their likely impacts would include a greater annual variability in the precipitation levels, leading to some parts of India getting wetter while others becoming drought-prone. Sea-level rise will increase saline-intrusion of groundwater, rendering it unsuitable for use. All of these will have a direct impact on surface and groundwater resources. Thus, the major water-related future. State of Indian Agriculture challenges to Indian agriculture will include the growing menace of ground water pollution, soil salinization and gradual decline in productivity especially in those areas, which witnessed the green revolution.

### **Need for gender mainstreaming in NRM projects**

Women played a key role in the conservation of basic support system such as land, water, flora and fauna (Swaminathan, 1985). Lotsmart 2008 in a study in Cameroon concluded that gender role play major role in natural resource management and neglect of gender will lead to conflicts between resource managers and users. Without gender consideration in programme and project all efforts to developing NRM in a sustainable manner goes vain. The study highlighted the gendered approach to NRM planning and management very much essential and used as an entry point of an project activity.

Gender roles varies from culture to culture. Their roles vary considerably between and within regions and are changing rapidly in many parts of the world, where economic and social forces are transforming the agricultural sector (Lotsmart, 2008. SOFA, 2011). To incorporate a gender approach, fundamental and basic need prior to planning mainstreaming



gender in NRM requires a gender framework analysis for understanding roles and responsibilities, knowledge of natural resources, identification of taboos and cultural practices associated with gender (Ajroud *et al.* 2015). Roshan Lal and Ashok Khurana 2011 stated that the women are major contributors in agriculture and its allied fields. Her work ranges from crop production, livestock production to cottage industry. From household and family maintenance activities, to transporting water, fuel and fodder. Despite such a huge involvement, her role and dignity has yet not been recognized. Women's status is low by all social, economic, and political indicators. Women's wage work is considered a threat to the male strong presence and women's engagement in multiple home based economic activities leads to under remuneration for their work. Women spend long hours fetching water, doing laundry, preparing food, and carrying out agricultural duties. Not only are these tasks physically hard and demanding, they also rob girls of the opportunity to study. The nature and sphere of women's productivity in the labor market is largely determined by socio-cultural and economic factors. Women do not enter the labor market on equal terms when compared to men. Their occupational choices are also limited due to social and cultural constraints, gender bias in the labor market, and lack of supportive facilities such as child care, transport, and accommodation in the formal sector of the labor market. Women's labor power is considered inferior because of employers "predetermined notion of women's primary role as homemakers. As a result of discrimination against female labor, women are concentrated in the secondary sector of labor market. Their work is low paid, low status, casual, and lacks potential upward mobility. The majority of women in the urban sector work in low paying jobs.

### **Gender as factor of production**

Among various inputs—seed, fertilizer, nitrogen, phosphatic, potassic, agrochemicals, diesel and electricity have found to increase crop yields. It is also mentioned mechanisation as one of the significant input that can add to crop productivity. (Srivastava, 1993). The economic advantages of mechanization are increase in productivity is 12-34%, seed cum fertilizer drill facilitates 20% saving. Enhancement in cropping intensity is 5-22%, increase in gross income and return of the farmers is 29-49%.

Besides mechanization, another important dimension recently added to the factors of production is gender. According to Christopher *et al.*, 1995.stated that women managed crops on plots gave higher yield than that of men managed crop with same allocation of inputs.( Table 1 & 2).

**Table 1. Participation of men and women in rainfed areas**

Land Preparation	Men
Cleaning of seeds and sowing	Women
Top dressing	Women
Gap filling	Jointly
Weed control	Women

Weed control	Men
Plant protection	Men
Harvesting	Women
Threshing	Men
Marketing	Men
Storage (/Bagging)	Women

**Table 2. Output, area and inputs per plot, by gender of cultivator**

	Crop output (thousands of FCFA*(per ha)	Area	Labour				Manure (kg per ha)
			Male	Female	Non- family	Child	
Male	79.9(186)	0.74 (1.19)	593 (1065)	248 (501)	106 (407)	104 (325)	2933 (11.155)
Female	105.4(286)	0.10 (0.16)	128 (324)	859 (1106)	46 (185)	53 (164)	764 (5 237)
t-statistic	-3.27	29.03	22.16	-21.31	6.89	7.08	7.68

**Source:** In Christopher et al 1995 and C Udry, *Gender, agricultural productivity and the theory of the household*, Discussion paper T1 94-118(1994): Timbergen Institute. Amsterdam-Rotterdam

**Table 3. Distributions of primary crops across plots**

Crop	Distribution of Crops (%)	
	Women plots	Men plots
White sorghum	20.4	20.4
Red sorghum	8.6	8.7
Millet	8.4	22.8
Maize	1.9	19.2
Groundnut	15.6	5.1
Cotton	0.7	11.1
Okra	12.4	0.6
Earthpeas/fonio	26.0	2.1
Other	6.0	10
Total	100.0	100.0

**Source:** In Christopher et al 1995 and C Udry, *Gender, agricultural productivity and the theory of the household*, Discussion paper T1 94-118(1994): Timbergen Institute. Amsterdam-Rotterdam

Gender is defined as the socially constructed roles and responsibilities attributed to men and women in a given culture. In general the division of labor in agriculture with regard to male and female labor roles is well defined. Participation of men and women differs with crop. Table 3 has clearly indicated participation of men and women labor in irrigated rice cultivation varies with participation in upland rice cultivation (Thelma Paris, 2008).

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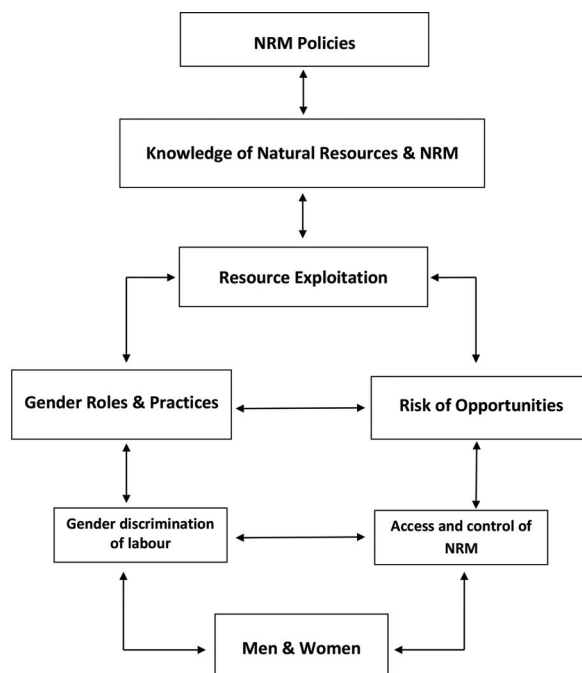
**Gender analysis for identifying gender sensitive projects:**

The UN and World Bank has stressed the need to incorporated gender concerns into many of the projects as to address gender equality into development methodology evolved (B N Sadangi, 2005) to identify gender roles and identify gender conflict areas to make research and extension projects more gender sensitive. Steps to identify gender roles and conflicts

1. Understanding gender roles and activity profile.
2. Defining gender relations.
3. Assessing resource endowments and resource use pattern in the area.
4. Identification of gender specific and gender common problems.
5. Evaluating gender perception of problems, their prioritization and cause-effect analysis.
6. Conceptualizing interventions (project) relevant to the situation.
7. Assessing people's perception about the projects or line of action.
8. Selecting the most feasible course of action.

**Table 4. Goals of farmer in farming systems resource of Ghana,**

Needs	Role of forest production in achieving needs	Men farmers		Women farmers	
		Order of priority needs	% of men	Order of priority needs	% of women
Adequate food, Nutrition & shelter	High	3	89.6	1	100.0
Domestic fuel-wood / energy	High	6	82.9	2	98.6
Health / medicinal plants	High	4	73.7	3	95.2
Higher income	Low	1	99.8	4	97.4
Better clothing & social status	Low	2	92.3	5	88.9
Better children's education	Low	5	93.1	6	79.8
Cultural values	Moderate	7	83.7	7	75.4



*Fig.1. Framework depicting gender inclusion NRM Policies Source: Lotsmart, 2008*

### **Gender differences in participation and Decision making in Watershed programmes**

The Study was carried out in Karnataka state watershed development programs at two levels: the project and watershed levels. In Karnataka state, at project level, the watershed development program was implemented in 22 districts, each administered by a project director. All the 22 project directors were included in the study and each was subjected with a questionnaire to ascertain their preparedness of integrating gender concerns into the watershed programmes. A questionnaire consisting of gender related activities at four different stages of watershed development programme namely preparatory, planning, implementation and evaluation stages, based on guidelines, was prepared and subjected to each of the project directors. At project level the responses were obtained only from nine project officials out of the twenty two project officials and those responses had been compiled and analysed to understand the extent of preparedness on integration of gender mainstreaming component in accordance to the new watershed guidelines of GOI.

At watershed level, in the second phase of study, based on the mean level of gender mainstreaming (GM) scores obtained, one district with above mean GM scores was chosen for detailed analysis as it would might throw more light on the participation pattern of gender in areas of planning, implementation and evaluation stages and work-wise patterns present in the watersheds. Out of the four districts namely Bengaluru, Chitradurga, Shimoga, Bellary that has received high mean GM scores; Bengaluru district

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was selected randomly. Two villages in Bengaluru district watershed were included and studied for the analysis of gender differences in terms of participation and decision-making in watershed programme. Thirty each of men and women stakeholders in different capacities and holding membership in committees and also trainees were contacted to elicit information on participation and contribution in decision making aspects both for phase-wise and work- wise information.

### **Details of the demographic and physical characteristics of study location**

The Kempalanatha micro watershed is situated south of Kanakpura Taluka with Grampanchayat headquarters at Hosadurga which is 28 kms from taluk headquarters. It covers 2 villages namely Kempalanatha and Guddeveerahosahalli. It has 897 ha. geographical area with 515 ha. as net area available for various treatments. The micro watershed has a total population of 1591 distributed among 2 villages with 450 males and 422 females and rest are children. The SC people constituted 6% and ST being one percent only. Farmers are very poor and are mainly dependent upon agriculture for their livelihood apart from sheep rearing. The arable area available for treatment comprised of both public and private lands to an extent of 58% of total geographical area. In the watershed, 29% of the area comes under marginal farmers, 31% with small farmers and rest 40% of area under big farmers. Average per family land holding in the project area is 2.35 ha. Most of the land is red loamy soils with maximum slope of 3-8%. Problems reported in these watersheds were uneven distribution and uncertain rainfall of 100-130 days with 2-3 prolonged long dry spells, low productivity, scarcity of water for both drinking and irrigation, less green cover and scarcity of fodder to the existing bovine population. The statistical tools used are mean, standard deviation, percentages and non-parametric test.

### **Gender mainstreaming at project level**

Gender mainstreaming (GM) scores were obtained in Karnataka state, at project level of study, from nine districts only out of the 22 project areas were contacted and are being presented in Table 4. It had indicated that women involvement at planning stage was high to medium in terms of watershed association membership (high), watershed committee membership (medium), in facilitating planning (medium), preparation of action plans (medium), in curriculum design for gender training (medium) and high participation in exposure visits and study tours. In preparatory phase women involvement at project level was high in terms of presence of women in watershed association and committee meetings as they were made compulsory, however, medium participation observed for participation in orientation workshops, identification of gender training institutions for training, and publication of resource materials. During implementation phase the project staff at district level have taken much care to provide equal wage rates which received high score followed by medium scores for gender activities namely organizing regular gender training, routing funds through women groups, representation of women from poor households, getting contributions from works in cash and labour and involving women in monitoring of activities based on action plans.

**Table 5. Gender differentials in participation and decision-making in Karnataka watershed**

Variable	Male	Female	t value
Participation (phase-wise)	25.5 (4.58)	24.23 (2.06)	-1.382 $p=0.0873$
Participation (work-wise)	6.07 (1.337)	7.5 (1.526)	3.879* $p=0.0001$
Decision-making	18.1 (2.67)	18.57 (1.52)	0.835* $p=0.0001$

### Gender differences in participation and decision-making in watershed development programmes of Karnataka State

In Figure 2 it is indicated that women participation in the area of works (SHG, manual and management) was found to be more significant than participation in planning, implementation and post project phases as these phases were not clear and distinct as much as works: manual and management. Both the men and women groups have identified themselves from works point of view rather from participation in planning, implementation point of view and therefore results found to be less significant from phase-wise participation category.

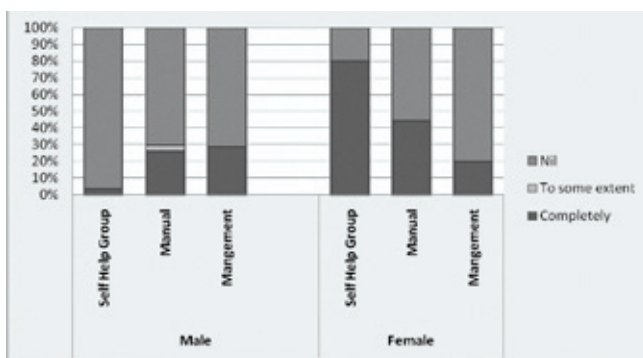


Fig. 2. Gender participation (work wise) in watershed program

From Table 5 it is indicated that participation was significant at implementation stage of watershed level (village level) particularly for men group which was more than women. This might be due to factors of institutionalized family structure and norms existing at watershed level. Participation in program that is in implementation phase men had more space and time to participate in *gramsabha* meetings, meetings on land use and crop planning, selection of plantation species and raising nurseries and participation in committee meetings which were mostly perceived as male oriented activities by women groups. In order to bridge gap between project and watershed levels more awareness programmes have to be intensified at watershed level for the impact to be felt on beneficiaries. It would be job of project officials to motivate men and women on that front. Satish kumar *et al.* (2013) opined that participation of beneficiaries in watershed

development activities is highly specific with the intervention and motivation play important role. Alston (2009) reiterated that to achieve gender equity, gender sensitization efforts have to be intensified so to reach grassroots level. And also a strong collaboration and consortia of gender specialists, women organizations and units at the national and international level have to work together and highlight culture specific gender issues and discriminatory outcomes. In Table 5, it is clearly indicated that gender differences in decision-making were significant in watershed development program. Women showed equal participation in decision-making as much as men. Surprisingly the mean averages found to be slightly higher with women and likely to decrease if not properly taken care of. Mohanty (2002) suggested that strong strategies are required to enable women exercise their decision-making abilities at committee level which can increase their confidence and awareness of their rights for them to be more assertive in meetings.

**Table 6. Gender participation (phase-wise) in watershed development programme**

Phase	Male		Female		t value	p
	Mean	SD	Mean	SD		
Planning	7.8	1.77	6.37	0.49	0.841	0.79
Preparatory	3.23	0.43	3.2	0.61	0.859	0.80
Implementation	7.6	1.38	6.3	1.42	- 3.50 *	0.004
Post project	25.5	1.0	5.9	0.80	5.05	1.0
Total	25.5	4.58	24.23	2.06	- 1.382	.0.087

\*significant at 1% level

(Source: Nirmala. G and M S Prasad. 2015)

Many other studies in watershed management have revealed that the participants from the tribal community viewed that water scarcity is the main obstacle in their socio-economic development and consequently a reason for their various physical, mental, and social health problems. They perceived that water scarcity resulted in seasonal agriculture, migration, water related infectious diseases, alcoholism and drudgery of women and watershed management and the developmental aspects associated with it was an inducer of improved public health, enhanced socio-economic status and also a cause of empowerment of the families. The overall empowerment of families and especially of women, enable them to claim their rights. Our research shows that local people's experiences identify the rights that suffer when their right to water is not respected, e.g. the right to health, the right to education and the gender dimension of this, the rights of girls and women. (Nerkar, Sandeep S. *et al* 2013); Ogunjimi & Adekalu 2002 income, and employment, especially for women in the \u201cslack\u201d period of rainfed agriculture. A study was undertaken to assess the practice of Fadama irrigation in Oyo and Osun states of Nigeria with a view to better understand the characteristic problems and needs. This paper reports on some general information on Fadama irrigation that are useful to project planners and assisting agencies. Fadama irrigation practice has increased significantly over the last 10 years because of increasing demand and high cost of vegetables produced by farmers. The majority of



farmers are assisted by World Bank funded States Agricultural Development Program (ADP, reported that Small-scale irrigation (FADAMA) by the Ministry of Health, Fadama farming should continue to expand beyond stream banks and areas adjacent to river bodies. It should cover more distant areas where the creation or exploitation of new sources of water such as wells and boreholes becomes feasible. If the demand for irrigated produce continues to exceed supply and profitability of dry season farming continues to increase, it is likely that more and more land will be brought under Fadama irrigation. However, Fadama farming, as being practiced, is fraught with many problems as highlighted by this work. These problems include irregular stream flow, high labor requirement for furrow irrigation and increasing cost of such labor, frequent pump breakdown, lack of knowledge about irrigation scheduling, inadequate land, low fertility, and erosion problems during the rainy season. Some suggested measures of ameliorating these problems are enumerated as follows. The use of trickle irrigation systems, especially micro-systems similar to the one proposed by Batcher *et al.*[12] instead of the sprinkler-system, would reduce fuel consumption and cost of pumping, and save water. However, since trickle irrigation is still new in Nigeria, research into water use patterns and economic feasibility of trickle irrigation must be supported to generate concrete data that can be used to arouse the interest of farmers in the system.

**Table 7. Soil and Water Management Practices Adopted by the Surveyed Farmers Practicing Small-Scale Irrigation in Osun and Oyo States of Nigeria**

Parameters	Osun (Percent of respondents)	Oyo
Soil conservation practices Fallowing		
Organic fertilization	48.8	23.3
Inorganic fertilization	46.5	57.3
Zero tillage	32.6	40.5
Mixed cropping	Nil	5.0
Ridging/mounds	18.6	20.0
Water conservation practices Mulching	18.6	7.5
Dug pond	Nil	Nil
Dredging of streams	25.6	22.5
Boring of wells	53.5	57.5
	9.3	14.0
	-	-

Udayakumara *et al* 2012 reported that the gender of the HH head had positive and significant effect on the adoption. The results showed that if a HH head is male, the odds of adaptation to SWC measures increase by a factor of 2844 after controlling for other factors. (Udayakumara *et al.* 2012)

### **Drudgery and Mechanization in India**

Drudgery reduction of farm women through technology intervention

Forty percent mechanization had been reported in tillage operations, 29% in sowing, 52% in threshing, 1% in harvesting and 34% in plant protection (Report of sub group on agriculture implements and Machines for 9<sup>th</sup> Five year plan, 1996)

Operations in rainfed agriculture carried out by women have related drudgery involved which could be reduced with small tools and implements. Drudgery is generally conceived as physical and mental strain, agony, monotony and hardship experienced by human beings. Women as constrained by illiteracy, malnutrition and unemployment, drudgery continue to add more to women's mental agony which makes 'working conditions' more difficult.

Weeding is invariably common activity for women in both rainfed and irrigated agriculture for a maximum period of 20- 30 days., 80- 90% in Agroforestry activities(Table 8). Chayya Badiger *et al.*, 2004 reported that drudgery from simple manual weeding can be reduced with either adoption of twin wheel hoe or Grubber hoe. The traditional tool called 'kurpi' used for weeding is very old and activity is monotonous and drudgery prone. An experiment carried out with farm women comparing manual weeding with improved tools indicated that the physiological cost of works was observed to be less with the improved weeder twin hoe (13.15 beats/min) and also for grubber weeder (18.17 beats/min)when compared to *kurpi*. Hence, both the improved weeders have proved to reduce the drudgery of farm women and saving of time while performing the weeding activity.(Table 3 & 4).

**Table 8. Circulatory stress and physiological parameters of the selected sample while working with the traditional and improved weeding implements**

Implement used	Physiological average working heart rate beats/min	Parameter average energy expenditure	Average TC-CW**beats)	Average physiological cost of work(beats/min)
Traditional method (kurpi)	108.77	8.58	568.03	18.91
Twin wheel hoe weeder	100.63	7.28	394.62	13.15
Grubber weeder	103.95	7.81	554.77	18.74

**Source:** Chhaya Badger, Suma Hasalkar and Shobha Huilgd, 2004, Kj-kilo joules, TCCW- Total cardiac cost of work

**Table 9. Rating of perceived exertion by the respondents while performing the weeding activity with traditional and improved technologies**

Technology	Rate of Perceived exertion
Traditional (kurpi)	Moderately heavy
Twin wheel hoe weeder	Light
Long handled weeder	Moderately heavy

**Source:** Chhaya Badger, Suma Hasalkar and Shobha Huilgd, 2004

### Case Study on reduction of women drudgery in dryland development

Reducing women drudgery in dryland development and growth is seen as important factor for women empowerment. Utility of small improved tools for crop production such as manual weeders were demonstrated and compared with farmers practice to demonstrate the efficiency of tools. From Table 5 revealed that weeding efficiency was 78% and 71.5% in Goplapur and Masaypally villages respectively, which is lower than farmers's practice i.e., 95-98%. This is due to the fact, in the later practice the weeding operations is

carried out in sitting posture slowly and with better visibility and control over the weeding uprooting. Where as in case of long handle tools the operation is carried out in standing position cautiously to avoid crop damage and keeping the blade little bit away from the crop rows. Some labour to the extent of 30-37% can be saved with uprooting of the left over weeds.

**Table 10. Performance of weeding implements in Goplapur and Masyapally villages**

Field	Field capacity ha	Weeding	Saving in
Operations	day-1	efficiency %	time %
Goplapur (Bajra + PP intercrop)			
T1: weeding with manual weeder	0.074	78	37.2
T2 : Weeding with sickle	0.047	98.1	
Masayapally (Sorghum + PP intercrop)			
T1: weeding with manual weeder	0.06	71.5	30
T2: weeding with Sickle	0.04	95	

*Source: UNDP report 2004 (B Sanjeev Reddy and G Nirmala)*

### **Strategies for Mainstreaming Gender in NRM**

Considering significance of women participation in NRM different strategies suggested were mainly based on experiences in various regions taken from literature. These strategies help sustain natural resources, provide means of effective management practices, prevention of degradation, rejuvenating of resources. Some strategies for mainstreaming gender are listed (Lotsmart, 2008).

**Control over land:** Most of the rural communities globally are male headed households where access to and control over land is natural. Women until being head of the households possess less control over the land rights. Legislation reform to enforce right and control of land empowers women so as to facilitate investment in land activities, enable decisions making power, cultivate own land for maximum returns and food security. Women must be aware of regarding their existing rights, access to judicial relief and redress, removing discrimination through legal reforms, and providing legal aid, assistance and counseling. Finally it is concluded that the rural women are exploited by land lords for their personal good and enrichment.

**Changing society's perceptions of women:** Women in patrilineal society are rarely co opted for development activities considering the triple roles of household activities. This perception need to be changed for building ecology and sustain natural resources. Women are treated as sub servant or personal property. In this regard government must formulate policies to enhance their skills and their work should be counted in economic indicators. Their knowledge of natural resources need to be exploited for sustainable development.

**Capacity-building among rural women:** Capacity-building plays important role in empowering women. According to Munmun *et al.* 2015 where only 4.3% had medium and 1.4% had low level of participation. Among nine selected characteristics of the rural

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women, two of these namely years of schooling and family farm size did not show positive significant relationships with their extent of participation in agricultural activities. On the other hand, extension media contact and access to training on agriculture showed positive significant relationship with their extent of participation in agricultural activities. The findings of the study indicate that the respondents of the study area have no alternatives other than agricultural activities. Here, more than half of respondents (62.9%, training and exposure to media is positively significant with women participation in land activities. It is stated that training broadens outlook and also provides skills to perform the activities effectively, extension contact makes people rational decision maker and informative. Training areas include improved agricultural practices, organizes group formation such as committees, water conservation groups and developing entrepreneurial and economic skills.

***Diversification of the rural economy and combating poverty:*** Women are primary users of land, water and forests and solely dependent on them for livelihood. Any disturbance to natural resources that benefits them would affect their livelihood. Majority of rural women live in poverty which being main cause of depletion of natural resources due to their sole dependence on it. Provision of alternate source of livelihoods to increase income levels found essential to prevent further degradation of land and soil fertility.

***Gender-sensitive awareness campaign:*** Awareness campaigns to be conducted for both men and women to understand the significance of women participation as co partners and main partners of right from planning NRM activities through form of drama, folk songs and any means matching o culture and literacy level of women.

***Holistic development approach:*** Involvement of all efforts of national and international agencies in gendered planning will be more comprehensive and fruitful. Integrated rural development with all Ministries coming together to plan a comprehensive national policy on gendering NRM projects at strategic level will yield deliverables that are effective in mainstreaming gender. Collaboration with public and private partners have to be encouraged. Women must be involved in decision-making bodies that have the potential to introduce structural changes. This action will bring some changes in the gender relations in the society.

***Empowering rural women:*** Women participation should be seen in mixed groups rather making exclusive groups for training and development activities. Such exclusive groups will only encourage disparity and less understanding with male co partners.

## **Conclusions**

Incorporating gender concerns into agriculture through mechanization can reduce drudgery and increases efficiency of work. This will affect the productivity of crop and overall performance and agricultural growth. Women role in agriculture need to be made more visible as 60 -70 % contribution in terms labour is from women work force. Reducing drudgery and saving of time has to be utmost concern of any agricultural project

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involving women. Empowerment by participation in decision- making from evidence so far suggests that a mixed- gender or joint decision making leads to better outcomes for environmental sustainability and food security, managing the multiple tradeoffs in landscape multifunctionality (Garence *et al.*, 2014).

## References:

- Ajrout, B., Westerman, K. and Edmond, J. 2015. Men and Women as Conservation Partners in Conflict Settings. *Peace Review: A Journal of Social Justice*, 27(2), pp.175–180. Available at: <http://www.tandfonline.com/doi/full/10.1080/10402659.2015.1037622#abstract>.
- Chhaya Badiger, Suma Hasalkar and Shobha Huilgd. 2004. Drudgery Reduction of farm women in weeding through technology interventions. *Proceedings of National seminar on Gender mainstreaming in Research, Extension and training-Problems and Priorities*. 35-27<sup>th</sup> October, 2005, pp 199-201.
- Christopher Udry, John Hoddinott, Harold Alderman, and Lawrence Haddad 1995 Gender differentials in farm productivity implications for household efficiency and agricultural policy. *Food policy* 30(5): 407- 433.
- FAO. 2009. Fact Sheet Gender and Dryland management. Gender roles in Transformation [www.fao.org/gender](http://www.fao.org/gender).
- Grace B Villamor, Meine van Noordwijk, utkur Djanibekov, Ma Elena Chiong- Javier and Delia Catacutan. 2014. Gender differences in land use decisions: shaping multifunctional landscapes, *Current Opinion in Environmental Sustainability*, 128–33.
- Lotsmart, N.F. 2008. Gender Roles and practices in natural resource management in the North West Province of Cameroon. *Local Environment*, 13(5): 461–475.
- Mayande, V. M. 2002. Improving production and productivity of drylands : role of improved implements. In *Training programme Compendium on improved implements for dryland agriculture* May 14-18, 2002 TTC, CRIDA
- Munmun, R. *et al.*, 2015. Women’s Participation in Agricultural Activities at Forest Land Areas of Bangladesh. *Journal of Social Sciences*, 11(1): 30–38.
- Nirmala. and Prasad, M.S. 2015. Gender Mainstreaming in Watershed development programmes in Karnataka State - A Critique. *Indian J. Dryland Agric. Res. & Dev.* 2015 30(1) : 94-100
- Nerkar., Sandeep, S., Tamhankar Ashok, J. Johansson, Eva; Stålsby Lundborg, Cecilia. *BMC International Health & Human Rights*. 2013, Vol. 13 Issue 1, p42-60. 19p. 4 Charts. DOI: 10.1186/1472-698X-13-42. , Database: Academic Search Premier
- NRAA. 2012. Prioritization of Rainfed Areas in India. Study report 4 Planning commission New Delhi
- Ogunjimi, L.A.O. and Adekalu, K.O. 2002. Problems and constraints of small-scale irrigation (FADAMA) in Nigeria. *Food Reviews International*, 18(4): 295–304.
- Rai, D.P. and Singh, K. 2008. Awareness , Attitude and Training Needs of Farmers about Recommended Practices in Watershed Development Programme, 8 (September), pp.89–91.

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- Roshan Lal and Ashok Khurana. 2011. Gender issues: the role of women in agriculture sector. *International Journal of Business Economics & Management Research*, 1 (1), Oct 2011, ISSN 2249 8826.
- Sadangi B.N., Dash, H.K. and Hema Pandey. 2005. Steps in Identifying Gender Sensitive research and Extension Projects-Experience from a case Analysis. *Proceedings of National seminar on Gender mainstreaming in Research, Extension and training-Problems and Priorities*. 35-27<sup>th</sup> October, 2005 pp 199-201.
- SOFA, 2011. The role of women in agriculture. ESAworking paper no. 11-02. Agricultural Development Economics Division, FAO.
- Swaminathan, M.S. 1985. Imparting rural women users perspective to agricultural research and, to agricultural research and impacting-draft paper for discussion. *Proceedings of the Workshop in Rice Farming System*, Apr. 10-13, Philippines, Los Banos.
- Thelma Paris. 2008. Addressing Gender issues in rice research and technology development: Challenges and opportunities to make a difference. Presentation made at NRCWA on Sept 7, 2008
- UNDP report. 2004. Empowerment of Women farmers through participatory dryland agricultural Technology Interventions. CRIDA, Hyderabad.
- Udayakumara, E.P.N., Shrestha, R.P. & Samarakoon, L., 2012. *Acta Agriculturae Scandinavica* , Section B &# x2013 ; Soil & Plant Science Mitigating soil erosion through farm-level adoption of soil and water conservation measures in Samanalawewa Watershed , Sri Lanka, (October), pp.37–41.





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## **Agro-Ecology Specific Rainwater Management Interventions for Higher Productivity and Income in Rainfed Areas**

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Rainfed agriculture constitutes 80% of global agriculture, and plays a critical role in achieving global food security. However, growing world population, water scarcity, and climate change threaten rainfed farming through increased vulnerability to droughts and other extreme weather events. Out of the total population of 7.3 billion, about 1 billion are food-insecure, and 60% of these live in South Asia (SA) and Sub-Saharan Africa (SSA). The importance of rainfed agriculture varies regionally, but it produces most food for poor communities in developing countries. The proportion of rainfed agriculture is about 95% in SSA, 90% in Latin America, 60% in SA, 65% in East Asia, and 75% in Near East and North Africa (Srinivasarao *et al.*, 2015).

With diverse climate, India has a high spatial and temporal variability in rainfall and temperature (Rao *et al.*, 2010). For example, southern Tamil Nadu experiences typical tropical temperatures with north-east monsoon being the main source of rainfall, whereas Punjab and Haryana in north-western India experience continental climates with extremes of temperatures varying from 45 to 50 °C in summer and near freezing temperatures in winter. The rainfed farming in north-western India is practiced under south-west monsoon rains. Thus, the climate of rainfed-dryland farming ranges from arid, semiarid to subhumid, with mean annual rainfall varying between 412 and 1378 mm. In terms of the distribution of rainfall, 15 million hectare (Mha) of the land receives an annual rainfall of <500 mm, 15 Mha of 500-750 mm, 42 Mha of 750-1150 mm, and 25 Mha of >1150 mm.

### **Water resources in India**

There has been a paradigm shift in water resources use in India since 1950s from communities (tanks and small water structures) to government (major and medium irrigation projects), and the private domain (groundwater). Groundwater provides about 70% of the irrigation and 80% of the drinking water. The principal source of water is precipitation (rainfall and snowfall), but only a part of the rainfall is stored as groundwater and the remaining is lost as runoff and evaporation. Out of the total annual precipitation (including snowfall) of around 4000 km<sup>3</sup> in the country, the availability from surface water and replenishable groundwater is 1869 km<sup>3</sup>, comprising of 690 km<sup>3</sup> (37%) of surface water, and 432 km<sup>3</sup> of groundwater (GOI, 2002). Total annual national water use may exceed the utilizable water resource by 2050 or 2060, unless significant changes occur

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through increased water storage and efficient water management. Thus, available water resources must be judiciously used. Nonconventional methods for utilization of water (e.g., through inter-basin transfers, artificial recharge of groundwater, and desalination of brackish or sea water) as well as traditional water conservation practices (e.g., rainwater harvesting, including rooftop rainwater harvesting) must be practiced further to increase the utilizable water resources.

### **Rainwater management**

In rainfed regions, due to the temporal and spatial variability and due to skewed distribution of rainfall, crops invariably suffer from moisture stress at one or the other stages of crop growth. Besides, the demand for water is growing continuously at an accelerated pace for meeting the requirements of various other sectors such as drinking, domestic, energy and industry, resulting in strain on water resource availability for agriculture sector. As the rainfall is the single largest source of water and water being the critical input for rainfed agriculture, effective rainwater management is critical for successful rainfed agriculture. The strategy for rainwater management in arid and semiarid regions mainly consists of selection of short duration and low water-requiring crops and conserving as much rainwater as possible so that crops can escape moisture stress during the growing period. In addition to *in-situ* conservation, efforts need to be made to divert the surplus water into storage structures, which can be used either as standalone resource or in conjunction with groundwater for meeting the critical irrigation requirements. In relatively high rainfall regions, the strategy is to conserve as much rainwater as possible and to harvest the surplus water for lifesaving irrigation and also for enhancing the cropping intensity, and to maximize returns from the harvested water. Apart from enhancing the availability of water by various methods, the approach is to increase the water-use efficiency by arresting losses associated with utilization of water and to maximize returns from every drop of harvested water. Watershed management is the flagship program of the country to enhance the water resource availability, which aims at reducing the severity of erosion, drought, and floods; optimize the use of land, water, and vegetation; and improve agricultural production and enhance the availability of fuel and fodder on a sustained basis.

### ***In-situ* moisture conservation**

As large part of rainfed agriculture consists of marginal and small holdings, *in-situ* moisture conservation measures are more practical. Location specific *in-situ* moisture conservation practices were developed by AICRPDA based on rainfall, soil types and overall agro-ecology (Table 1). Treating land before commencing rains through summer ploughing, broad bed furrow (BBF) raised and sunken bunds etc facilitates the maximum intake of rainwater into soil profile thus successful crop production is possible in rainfed regions of India. Ridge furrow, sowing across the slope and paired row sowing are important water conservation measures which have proved to be highly effective not only for water

conservation but also draining out of excess rainwater during heavy rains. The yield improvements with these technologies varied from 20 to 40% depending upon rainfall and its distribution. BBF and ridge-furrow technology implementation have saved soybean and maize crops during 2013 from heavy rains in Malwa regions of MP and Vidarbha region in Maharashtra and crops without these interventions completely failed. Based on the success of these technologies, Government of Maharashtra is implementing these *in-situ* moisture conservation measures in large scale under Dryland Farming Mission of Maharashtra state.



*In-situ moisture conservation through conservation furrow*

**Table 1. Recommended soil and water conservation measures for various rainfall zones in India**

Seasonal rainfall (mm)			
< 500	500-700	750-1000	> 1000
Contour cultivation with conservation furrows	Contour cultivation with conservation furrows	BBF (Vertisols) conservation furrows	BBF (Vertisols)
Ridging	Ridging	Sowing across slopes	Field bunds
Sowing across slopes	Sowing across slopes	Tillage	Vegetative bunds
Mulching	Scoops	Lock and spill drains	Graded bunds
Scoops	Tied ridges	Small basins	Level terrace
Tied ridges	Mulching	Field bunds	
Off-season tillage	Zing terrace	Vegetative bunds	
Inter-row water harvesting systems	Off-season tillage	Graded bunds	
Small basins	BBF	<i>Nadi</i>	
Contour bunds	Inter-row water harvesting system	Zing terrace	
Field bunds	Small basins		
<i>Khadin</i>	Modified contour bunds		
	Field bunds		

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**Leveling and bunding:** Leveling of the soil and bunding is the simplest and most important operation required to effectively utilize the rainwater and uniform distribution of fertilizers and seeds under rainfed situations. Different types of bunds are suggested depending on soil type and rainfall pattern. For Alfisols having slopes more than 1.5%, contour bunding is found to be the most promising. Well designed and maintained contour bunds on Alfisols conserve soil and water more effectively than graded and field bunds (Pathak *et al.*, 1985). Graded bunds are suggested in areas having higher rainfall with less permeable, deep heavy soils. In Northern Karnataka adoption of graded bunds in Vertisols for pigeonpea, horsegram, blackgram, greengram and chickpea recorded higher seed yields by 17, 54, 12, 25 and 23%, respectively compared to control in rainfed environments (Guled *et al.*, 2003).

**Tillage:** Summer/off-season tillage is one of the most important traditional practices in rainfed areas. Off-season tillage has been found to be useful in increasing rainwater infiltration and minimizing water evaporation by a ‘mulching’ effect. Deep ploughing plays an important role in stabilizing the productivity of rainfed pulses through *insitu* soil moisture conservation (AICRPDA, 2003). Summer tillage with two-bottom mouldboard plough utilizing residual moisture or pre-monsoon showers is recommended to make the land ready for planting in eastern Uttar Pradesh. This practice helps in greater retention of rainwater (36% higher than conventional method) and enhances the yield of pigeonpea by 86% compared to farmers’ practice (Venkateswarlu *et al.*, 2009). In another experiment in medium deep black soils at AICRPDA centre Arjia (Bhilwara district, Rajasthan), *in situ* moisture conservation with summer deep ploughing with raised bed of 40 cm width gave highest blackgram yield (1243 kg/ha), rainwater use efficiency and lowest runoff and soil loss compared to farmers’ practice of flat bed (AICRPDA, 2011). It is evident from several experiments that the effects of deep tillage could last for 2 to 5 years depending upon the soil texture and rainfall. On Alfisols, the problem of crusting and sealing is encountered during early stages of crop growth resulting in uneven germination and plant stand. Under stress conditions, shallow tillage as an additional inter-cultivation has been found to be effective in breaking up the crust, improve infiltration, and reduce moisture losses through evaporation by creating dust mulch (AICRPDA 2011).

**Compartmental bunding:** It is another *in situ* moisture conservation practice in medium to deep Vertisols in post-monsoon predominant cropping areas like northern dry zone of Karnataka. Dividing the field into parcels of 4.5 x 4.5 m and 3 x 3 m on lands having slopes of 2% and 3%, respectively is called compartmental bunding (Guled *et al.*, 2003). In a study conducted at Bijapur, there was reduction in runoff in compartmental bunded plots (6.8%) compared to conventional practice (15.6%). It is an affordable technology, which can be adopted by employing a simple bund former.

**Land configuration:** Raised land configurations such as broadbed and furrow (BBF), raised and sunken beds etc. not only help in efficient conservation of rainwater but also drain out excess water during high rainfall events, particularly in black soils, thereby enhance the productivity of crops. BBF system refers to modifying the land surface into alternative wide (1.5 m) beds and narrow (50 cm) furrows. This system has been found

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useful in vertisols of low to medium rainfall (<1000 mm) regions. In Southern Tamilnadu, *in-situ* moisture conservation thorough BBF in greengram recorded higher seed yield (750 kg/ha) over flat bed sowing (630 kg/ha) (AICRPDA-NICRA, 2016). Similarly, raised and sunken bed system is advocated for vertisols of high rainfall (>1000 mm) regions. In northwest plain zone, land configuration improved the productivity of pigeonpea by 40% with raised bed at 2.7 m width compared to flat bed system. In Bastar plateau region of Chhattisgarh, ½ feet raised/sunken bed improved seed yield of cowpea by 35% compared to flat bed method (3454 kg/ha) (AICRPDA, 2015).

In eastern Uttar Pradesh, ridge-furrow planting of pigeonpea (on ridge) and rice (in furrows) both in uplands and medium lands helped in runoff modulation, crop diversification, risk reduction and disruption of pest cycle. This system produced a rice equivalent yield of 8866 kg/ha and 47% higher income as against 3500 kg/ha of rice with farmers' practice of sole rice under flat bed planting. In Kandi region of Punjab, ridge planting of greengram and blackgram gave 33 and 12% higher seed yields compared to flat planting, respectively (AICRPDA-NICRA, 2016).

**Conservation furrows:** Conservation furrows are the opening of furrows parallel to rainfed crop rows across the land slope, with a country plough, 3 to 4 weeks after the germination of the main crop (Venkateswarlu *et al.*, 2008). During runoff causing rainfall events, the rainwater gets concentrated within these furrows, infiltrates into the soil (root zone) and is available to the crop for meeting the evapo-transpiration demand for a longer duration compared to no furrow. Large scale demonstrations in Karnataka proved that finger millet + pigeonpea intercropping system (8:2) with staggered moisture conservation furrow gave higher net returns (Rs. 14198/ha) as compared to farmers' practice (Ramachandrappa *et al.*, 2010). In scarce rainfall zone of Andhra Pradesh, *in-situ* moisture conservation through opening of conservation furrows recorded 9% higher seed yield of pigeonpea (738 kg/ha) compared to control (AICRPDA-NICRA, 2016). Set furrow cultivation is another effective micro-site improvement process which conserves rainwater effectively and offers excellent drought proofing. In this technique, crop rows are set permanently by opening deep furrows of 25 to 30 cm at wider distance (135 cm) and all the inputs (crop residues, manures and fertilizers) are applied in the set furrows before sowing. At Bijapur (Vertisols), set furrow with residue incorporation + glyricidia (5 t/ha) in pigeonpea + groundnut intercropping (2:4) resulted in efficient *in-situ* moisture conservation and gave higher pigeonpea equivalent yield (1864 kg/ha) and net returns (Rs. 71931/ha) than farmers' practice (1479 kg/ha) (AICRPDA, 2015).

**Contour farming:** While tillage helps in improving water intake, contour cultivation boosts it further by building up temporary water storage capacity in furrows across the slope. Contour cultivation is, however, difficult to achieve on small and narrow fields. Under such situations, cultivation across the slope is a viable alternative for efficient *in-situ* moisture conservation. It consists of performing all agricultural operations (tillage, sowing, inter-cultivation etc) along the contour. Taley (2012) reported that the soil moisture content increased by 22-75% due to contour cultivation and enhanced the productivity of greengram (62.5%), pigeonpea (75%) and soybean + pigeonpea (46-50%). Further, due to



cultivation of chickpea across the slope, there was increase in soil moisture content (16-36%), chickpea yield and rainwater use efficiency (RWUE) in deep black soils. Similarly, contour cultivation with opening of contour furrows at 20 m HI and formation of square basins (20 x 20 m) enhanced yield of chickpea by 50 and 66.6%, respectively.

**Mulching:** Mulching is useful for achieving higher rainfall infiltration, reduced soil erosion, structural stability and minimize soil moisture losses through evaporation. Different materials such as crop residues, green manure, sand, polyethylene and pebbles can be used as mulch. Soil water content under sand mulch at any point of time in a year could be 85-98% compared to no mulch. The practice of sand mulching in sodic Vertisols of northern Karnataka enables double cropping of groundnut or green gram in *khariif* followed by sorghum or chickpea in *rabi*. The cost of sand application can be recovered within 2 years of cropping. A uniform layer of pebbles on soil surface will prevent transfer of heat from the surrounding air to the soil, reducing evaporation losses. It also helps control runoff water effectively. Large scale demonstrations conducted on an area of 500 ha in Bagalkot taluk of Karnataka clearly indicated the yield advantage of 200% in greengram (Guled *et al.*, 2003). In scarce rainfall zone of Andhra Pradesh, *in-situ* moisture conservation through conservation furrow and mulching with groundnut shells recorded higher seed yield of pigeonpea (610 kg/ha) compared to control (270 kg/ha). Similarly, in Central Maharashtra, *in-situ* moisture conservation through mulching with crop residues gave 8-10% higher yields of greengram, blackgram and pigeonpea compared to no mulching (AICRPDA-NICRA, 2016). The effect of mulches on crop productivity and profitability in different locations are given in Table 2.

**Table 2. Effect of various mulch materials on crop productivity and profitability at different locations in India**

Location	Crop	Type of mulch	Yield	increase	Net return (Rs/ha)	
			over mulch (%)	without mulch (%)	With mulch	Without mulch
Ballowal Saunkri (Punjab)	Sarson	Paddy straw		41.9	9820	4453
	Lentil	Subabul		35.2	9042	4462
	Maize	Sugarcane trash		56.8	8359	6600
	Wheat	Paddy straw		59.7	15067	12358
SK Nagar (Gujarat)	Castor	Crop residue		28.5	16594	12595
Indore	Pigeonpea	Crop residue		8.7	23812	21766
(Madhya Pradesh)	Soybean	Polythene		42.7	34839	23666
Varanasi (Uttar Pradesh)	Upland rice	Straw		19.4	3799	1802

**Source:** Compiled by authors from Annual Reports of AICRPDA

### **Ex-situ rainwater harvesting and efficient utilization**

The importance of rainwater harvesting has increased in recent years due to the increased rainfall variability, heavy rains and depletion of groundwater levels. Rainwater harvesting and recycling through farm ponds, restoration of old rainwater harvesting structures in dryland/rainfed areas, percolation ponds for recharging of open wells, bore wells and

injection wells for recharging ground water are taken up for enhancing farm level water storage in drylands. Watershed management is the flagship program of the country to enhance the water resource availability, which aims at reducing the severity of erosion, drought, and floods, optimize the use of land, water and vegetation, and improve agricultural production and enhance the availability of fuel and fodder on a sustained basis.



*Rainwater harvesting in farm ponds*

It has been estimated that, 27.5 M ha of rainfed area of the country, excluding the very arid and wet areas, can contribute an amount of 114 billion m<sup>3</sup> of water for water harvesting which is adequate to provide one supplementary irrigation of 100 mm depth to 20 M ha during drought years and 25 M ha during normal years (Sharma *et al.*, 2010). Harvesting the runoff water and storing it in farm ponds is a possibility in rainfed regions and the size of the pond depends on the rainfall, topography, and soils of the region. The so harvested water during the *kharif* (rainy) season can be used either for supplemental irrigation during dry spells coinciding with critical crop stages in *kharif* or for establishment of *rabi* (winter) crops. The advantages of supplemental irrigation are significant and considerable improvement in crop yields has been noticed at locations of various AICRPDA centers as given in Table 3. The rainwater harvesting and efficient utilization as supplemental irrigation to rainfed crops during prolonged periods of dry spells enhanced productivity and profitability (Ravindra Chary *et al.*, 2016) (Table 4).

**Table 3. Effect of one supplemental irrigation (5 cm) from harvested rainwater in farm ponds on yield of rainfed crops**

Crop	Yield (kg/ha)	Yield increase due to irrigation (%)	Location
Sorghum	1270	19	Anantapur
Sorghum	1350	32	Bijapur
Maize	4333	71	Arjia
Cotton	1730	14	Kovilpatti
Soybean	2050	14	Indore
Castor	1320	31	Hyderabad
Wheat	2143	25	Ballawal Saunkhri
Pea	2207	44	Varanasi
Barley	3001	32	Agra
Safflower	1014	48	Parbhani

*Source: Compiled by authors from Annual Reports of AICRPDA*



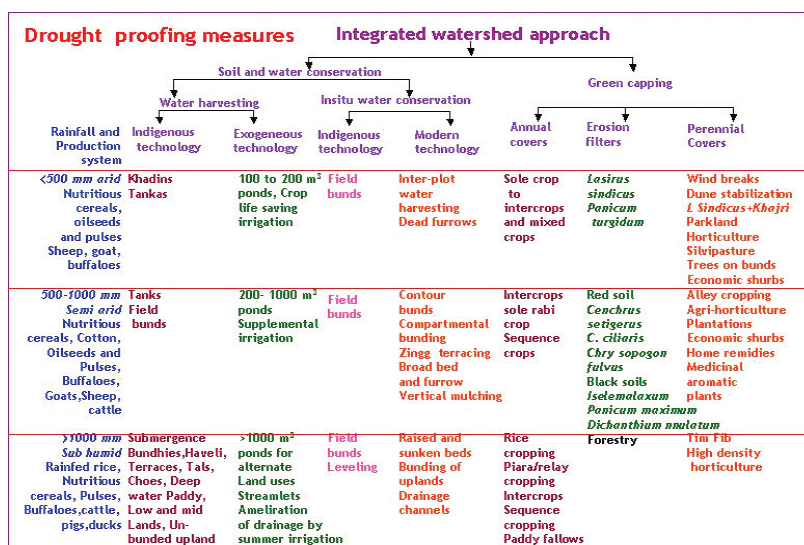
**Table 4. Response of pulses to supplemental irrigation**

Location/ State	Climate (MARF* mm)	Dominant soil type	Crop	Yield (kg/ha)		Increase in yield (%)	Source
				Irrigated	Control		
Akola (Maharashtra)	Semiarid hot moist (824)	Vertisols	Pigeonpea Chickpea	1000 1000	600 375	67 167	Taley (2012)
Rewa (Madhya Pradesh)	Sub humid hot dry (1088)	Vertisols	Chickpea	1905	1270	50	AICRPDA (2010)
Agra (Uttar Pradesh)	Semiarid hot dry (665)	Inceptisols	Lentil	1353	1119	21	AICRPDA (2011)
Parbhani (Maharashtra)	Semiarid hot moist (901)	Vertisols	Pigeonpea	748	435	72	AICRPDA- NICRA (2016)

\*Mean annual rainfall

## Watershed approach for rainwater management

Watershed management is a holistic approach towards optimizing the use of land, water and vegetation to alleviate drought, moderate floods, prevent soil erosion, and improve water availability and increase fuel, fodder, fibre and agricultural production on a sustained basis. Integrated watershed management (IWM) is the key to conservation and efficient utilization of vital natural resources viz., ‘soil’ and ‘water’, particularly in rainfed agriculture where water is the foremost limiting factor for agricultural production. The prioritized steps involved in resource conservation are the use of practices based on the existing traditional systems. (Fig . 1).



**Fig. 2. Drought proofing measures in arid, semi-arid and sub-humid regions (Vittal *et al.*, 2003)**

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Meta analysis of 311 watershed case studies from different agro-eco regions in India revealed that watershed programs benefitted farmers through enhanced irrigation areas by 33.5%, increase in cropping intensity by 63%, reduction in soil loss by 0.8 t/ha and runoff by 13% and improvement in groundwater availability. Economic assessment showed that the watershed programs were beneficial and viable with a benefit-cost ratio of 1:2.14 and an internal rate of return of 22% (Joshi *et al.*, 2005).

### **1. Scientific rainfed land use planning**

Scientific land use planning in drought prone regions is one of the rational approaches for drought mitigation. The ICAR- National Agricultural Technology Project (NATP)- Mission Mode Project on Land Use Planning for Managing Agricultural Resources - Rainfed Agro-ecosystem was implemented by 13 AICRPDA centers in an area of 5258 ha in 16 microwatersheds across arid, semiarid and sub-humid agro-eco-sub-regions. Based on the evaluation of the existing land use and land evaluation for suitability of crops, 932 on-farm trials were conducted in 603 ha at 1294 sites on 132 soil sub-groups on varying topo-sequences and the outcome distinctly indicated that in a microwatershed at cadastral level (1:10000/25000) the scientific land use on a soil-landscape continuum could enhance the land productivity from 20 to 50% compared to traditional land use. The cadastral level soil-site specific cropping systems centred land use modules were developed/identified, for example, *Mucuna utilis* on alfisols of Bangalore, pigeonpea+greengram, coriander and chickpea+senna inter/relay crops together in post monsoon Vertisols of Kovilpatti, sesame+castor in Vertisols of Akola, rainfed rice+pigeonpea in inceptisols of Varanasi, groundnut –vamu sequence in Vertisols of Bellary, safflower with compartmental bunding in deep Vertisols of Solapur (Ravindra Chary *et al.*, 2008; Final Report -NATP-MMALUP-III- 28-Rainfed agroecosystem, 2005)

Further, based on the cadastral level soil resource information in the microwatersheds, Ravindra Chary *et al.* 2005 developed Land Management Units (LMUs) for land resource management since these units are homogeneous and has a wider application. As a first step, the Soil Conservation Units (SCUs) and Soil Quality Units (SQUs) were delineated and secondly, the SCUs and SQUs are merged in GIS environment to delineate land parcels in to homogenous Land Management Units with farm boundaries. A resilient, less risk prone farming system based on the land requirements and farmers' capacities can be developed to mitigate the drought and to address the unabated land degradation and imminent climate change. The SCUs are basically for soil and water conservation prioritized activities to mitigate drought and could be linked to programmes like MG National Rural Employment Guarantee Scheme (MGNREGS) in a watershed/ village to create physical assets like farm ponds etc. SQUs are to address soil resilience and improve soil organic carbon, problem soils amelioration and wastelands treatment and linked to various schemes and programmes in operational like National Horticultural Mission (NHM), Rashtriya Krishi Vikas Yojana (RKVY), etc. LMUs would be operationalized at farm level for taking decisions on arable, non-arable and common lands for cropping, agro-forestry, agro-horticulture, etc., and further, for levelling the most fragile land parcels for eco-restoration. Rainfed land use planning modules should be based on these units for risk minimization, enhanced land

productivity and income, finally for drought proofing. An example of delineation of these units for the Kaulagi watershed, Bijapur district, Karnataka is shown in Fig. 3, 4, and 5.

SCU	Details	Area (%)
2	Deep + low erosion	50.23
3	Shallow + very low erosion	7.68
4	Shallow + moderate erosion	1.61
5	Deep + moderate erosion	1.17
6	Deep + high and very high erosion	1.99
7	Very shallow + low erosion	0.83
8	Very shallow + moderate erosion	27.31
9	Very shallow + high and very high erosion	9.18

SQU	Details	Area (%)
1	Non gravel + neutral (pH) + low (OC) + normal (EC) + calcareous ( $\text{CaCO}_3$ )	1.67
2	Non gravel + neutral (pH) + low (OC)+ high (EC) + calcareous	36.76
3	Non gravel + alkaline (pH) + low (OC)+ normal (Eke) +calcareous	1.17
4	Gravel + alkaline (pH) + high (OC) + normal (EC) + calcareous	15.71
5	Gravel + alkaline (pH) + medium (OC)+ normal (EC) + calcareous	10.07
6	Gravel + alkaline (pH) + low (OC) + normal (EC) + calcareous	2.12
7	Gravel + alkaline (pH) + low (OC) + critical (EC)+ calcareous	7.51
8	Extremely gravel + alkaline (pH) + low (OC) + normal (EC) + calcareous ( $\text{CaCO}_3$ )	25.00

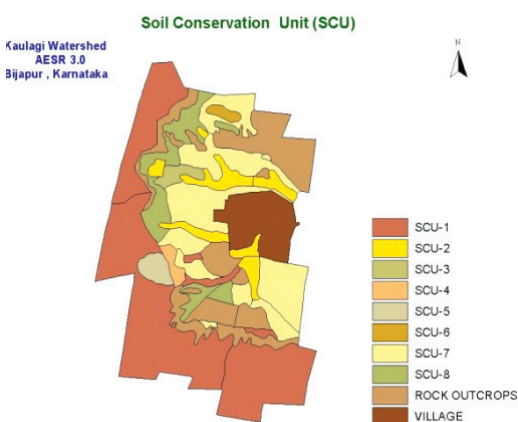


Fig. 3. Soil Conservation Units (SCUs) in the Kaulagi watershed, Bijapur district, Karnataka

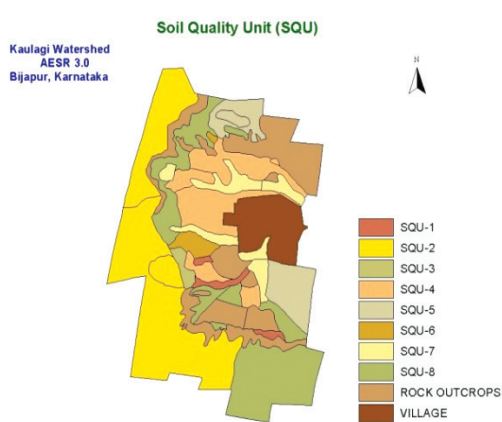


Fig. 4. Soil Quality Units (SQUs) in the Kaulagi watershed, Bijapur district, Karnataka

LMU	SCU	SQU	Soil Series
LMU-1	SCU - 1	SQU - 1	15 F
LMU - 2	SCU - 1	SQU - 2	1 A/2A
LMU - 3	SCU - 1	SQU - 8	5 B
LMU - 4	SCU - 2	SQU - 6	9 D
LMU - 5	SCU - 2	SQU - 7	8 D/9D/10D/11D
LMU - 6	SCU - 3	SQU - 4	12 E
LMU - 7	SCU - 4	SQU - 3	4 C
LMU - 8	SCU - 5	SQU - 2	3 A
LMU - 9	SCU - 6	SQU - 5	17 G
LMU - 10	SCU - 7	SQU - 4	12E/132E/14E
LMU - 11	SCU - 7	SQU - 5	16G
LMU - 12	SCU - 7	SQU - 6	13E
LMU - 13	SCU - 7	SQU - 8	18H
LMU - 14	SCU - 8	SQU - 8	18H

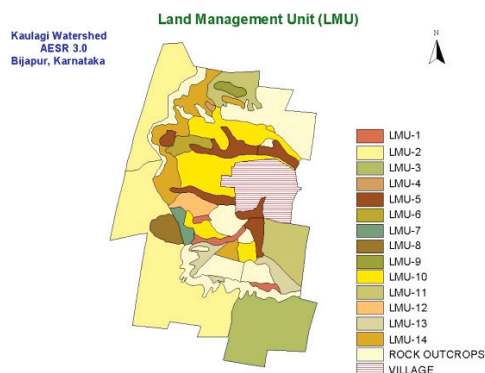


Fig 5. Land Management Units (LMUs) in the Kaulagi watershed of Bijapur district, Karnataka

Participatory land use planning is a buzzword for achieving the different goals of the various stakeholders. In stressed ecosystems like rainfed where in the major crop based production systems are established as best land use planning over a period of time, no single land use or single criteria has sustained the land productivities, incomes, ecosystem and finally the livelihoods reasons being highly complex situations of risk, diverse socioeconomic settings and subsistence agriculture. Thus, land use planning in drought prone areas majorly occurring in rainfed regions should aim at increased land productivity in totality through various means from annuals to perennials by coping with aberrant weather causing drought and inherent unabated land degradation. The final aim is to build a bio-diverse mixed farming system model for individual farmer to sustain the farming system and achieving the goals of food, nutritional economic and ecological securities with complimentary benefits of drought irrigation or drought proofing and land management and a buffer to impact of land use change.

## References

- AICRPDA. 2003. Annual Report 2002-03, All India Coordinated Research Project for Dryland Agriculture, CRIDA, and Hyderabad. 274 p.
- AICRPDA. 2011. Annual Report 2009-10, All India Coordinated Research Project for Dryland Agriculture, CRIDA, and Hyderabad. 420 p.
- AICRPDA. 2015. Annual Report 2014-15, All India Coordinated Research Project for Dryland Agriculture, CRIDA, and Hyderabad. 336 p.

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- AICRPDA-NICRA. 2016. Managing Weather Aberrations through Real Time Contingency Planning AICRPDA-NICRA Annual Report, 2015-16, All India Coordinated Research Project for Dryland Agriculture, ICAR-Central Research Institute for Dryland Agriculture, India. 226 p.
- GOI, 2002. National Water Policy. Government of India, Ministry of Water Resources, 10 p.
- Guled, M.B., Lingappa, S., Itnal, C.J., Shirahatti, M.S. and Yaranal, R.S. 2003. Resource conservation and management in rainfed agro-ecosystem- A compendium for research and development. Technical Bulletin 34, UAS, Dharwad. 268 p.
- Joshi, P. K., Jha, A. K., Wani, S. P., Laxmi Joshi and Shiyani, R. L. 2005. Meta analysis to assess impact of watershed program and people's participation", Comprehensive assessment research report 8. Colombo, Sri Lanka: Comprehensive Assessment Secretariat, IWMI. pp. 18.
- Pathak, P., Miranda, S.M. and El-Swaify, S.A. 1985. Improved rainfed farming for the semi-arid tropics: Implications for soil and water conservation. (In) *Soil erosion and conservation* (El-Swaify, S.A., Moldenhauer, W.C. and Andrew, L. Eds.), Soil Conservation Society of America, Iowa. Pp. 338-354.
- Ramachandrappa, B.K., Mariraju, H., Balakrishna Reddy, P.C. and Ashokkumar, H.P. 2010. Impact of operational research project for dryland agriculture. *Indian Journal of Dryland Agricultural Research & Development* **25**: 92-98.
- Rao, G.S.L.H.V.P., Rao, G.G.S.N. and Rao, V.U.M. 2010. Climate change and agriculture over India. PHI Learning Private Limited, New Delhi, 328 p.
- Ravindra Chary, G., Gopinath, K.A., Raju, B.M.K., Srinivasarao, Ch., Kandpal, B., Bhaskar, S., Narendra Kumar and Narsimlu, B. 2016. Natural resource management based approaches for enhancing pulses production in rainfed areas. *Indian Journal of Agronomy* 61 (special issue): S199-S213.
- Ravindra Chary, G., Venkateswarlu, B., Maruthi Sankar, G.R., Dixit, S., Rao, K.V., Pratibha, G., Osman, M. and Kareemulla, K. 2008. Rainfed Agro-Economic Zones (RAEZs): A Step towards Sustainable Land Resource Management and Improved Livelihoods. Lead Paper. National Seminar on Land Resource Management and Livelihood Security, the Indian Society of Soil Survey and Land Use Planning, 10-12 September 2008, Nagpur, India. p. 70.
- Ravindra Chary, G., Vittal, K.P.R., Ramakrishna, Y.S., Sankar, G.R.M., Arunachalam, M., Srijaya, T. and Bhanu, U. 2005. Delineation of soil conservation units (SCUs), soil quality units (SQUs) and land management units (LMUs) for land resource appraisal and management in rainfed agro-ecosystem of India: A conceptual approach. Lead Paper. National Seminar on Land Resources Appraisal and Management for Food Security, Indian Society of Soil Survey and Land Use Planning, National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Nagpur, India, 10-11 April 2005. p. 212.
- Sharma, B.R., Rao, K.V., Vittal, K.P.R., Ramakrishna, Y.S. and Amarasinghe, U. 2010. Estimating the potential of rainfed agriculture in India: Prospects for water productivity improvements. *Agricultural Water Management* 97(1): 23-30.
- Srinivasa Rao, Ch., Lal, R., Prasad, J.V.N.S., Gopinath, K.A., Singh, R., Jakkula, V.S., Sahrawat, K.L., Venkateswarlu, B., Sikka, A.K. and Virmani, S.M. 2015. Potential and Challenges of Rainfed Farming in India. In: Sparks, D.L. (Ed.), *Advances in Agronomy*, pp. 113-181.
-

- 
- Taley, S.M. 2012. Enhancing crop productivity in rainfed agriculture through rainwater conservation. (In) *Souvenir and abstracts of seminar on breaking yield barriers in major field crops*, 6-7 January 2012, Akola Chapter of Indian Society of Agronomy, Akola, India. pp 83-92.
- Venkateswarlu, B., Mishra, P.K., Ravindra Chary, G., Maruthi Sankar, G.R. and Subba Reddy, G. 2009. Rainfed farming – A compendium of improved technologies. All India Coordinated Research Project for Dryland Agriculture, CRIDA, Hyderabad. 132 p.
- Venkateswarlu, B., Ramakrishna, Y.S., Subba Reddy, G., Mayande, V.M., Korwar, G.R. and Prabhakar, M. 2008. Rainfed Farming: A profile of doable technologies. CRIDA Technical Bulletin, 48 p.
- Vittal, K.P.R., Singh, H.P., Rao, K.V., Sharma, K.L., Victor, U.S., Chary, G.R., Sankar, G.R.M., Samra, J.S. and Singh, G. 2003. Guidelines on drought coping plans for rainfed production systems. All India Coordinated Research Project for Dryland Agriculture, Central Research Institute for Dryland Agriculture, Indian Council of Agricultural Research, Hyderabad. 39 p.





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# Water Use Efficiency in Livestock Production Management: A Key Area for Improving Farmers' Income in Drylands

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Demand for meat and milk is projected to be more than double over the next two decades in developing countries. The major factors driving this rising demand are population growth, increased awareness towards balanced diet, increased urbanization and higher incomes. If livestock production is to keep pace with demand, the imperative is to enhance productivity per animal with minimal resource use and reduced wastage. Livestock contribute to livelihood of poor and food insecurity in drylands in many ways. They are an important source of cash income, and offer risk management options to reduce vulnerability, social networking instruments and social security capital. They provide major benefits in term of manure and draft power to enhance soil fertility and facilitate facility to sustainable intensification of farming systems; transport to markets and power for post-harvest operations; usage of common property grazing lands, which are especially vital to the welfare of the landless; source of income diversification; and high-quality protein and energy to the diets of food and nutrition insecure, as well as essential micronutrients such as calcium, iron, zinc, retinal, thiamine, and vitamins A, B<sub>6</sub> and B<sub>12</sub>, often lacking in cereal-based diets. Livestock products provide one third of the human protein intake, but also consume almost one third of the water used in agriculture globally. Most of the world's animal production comes from rainfed mixed crop-livestock systems in developing countries and from intensive industrialized production in developed countries. Livestock production systems are rapidly changing in response to various potential drivers, mainly in terms of policy adaptation, investment and technology options. With increasing demands for animal products, along with increasing global water scarcity and competition for water, improving livestock water productivity (LWP) has become essential.

## **Livestock water productivity (LWP)**

Agriculture accounts for 92% of the freshwater footprint of humanity; almost one third relates to animal products which is likely to increase further. Mekonnen *et al.* (2011) showed that animal products have a large water footprint (WF) as compared to crop products. LWP was first defined by Peden *et al.* (2007) as the ratio of livestock products and services to the water depleted and degraded in producing these; it can also include water depleted in slaughter houses and milk processing facilities. Livestock grazed on arid and semi-arid pastures utilize water that cannot be used for crops and would be depleted through evapotranspiration before it could enter groundwater and surface water

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bodies. Such water would be valued less than water in an irrigation scheme that can be used for growing high value vegetable crops. A consideration of the value of water could lead to demand-side management that would foster a rebalancing of water use among agricultural sectors. Especially for livestock production in areas of low potential and in smallholder systems, such considerations would show that livestock are very efficient in making productive use of water that is of low value for other sectors. There are three main factors driving the WF of meat; they are feed conversion efficiency (feed amount per unit of meat obtained), feed composition and feed origin. Feed conversion efficiency improves from grazing to mixed to industrial systems, because animals in industrial systems get more concentrated feed, move less, are bred to grow faster and slaughtered younger. This factor contributes to a general decrease in WFs from grazing to mixed to industrial systems. The second factor is feed composition, particularly the ratio of concentrates to roughages, which increases from grazing to mixed to industrial systems. Concentrates have larger WFs than roughages, so that this factor contributes to a WF increase, especially blue and grey WFs, from grazing and mixed to industrial systems. The third factor, the feed origin, is important because water use related to feed crop growing varies across and within regions. The overall resultant WF of meat depends on the relative importance of the three main determining factors. In general, beef has a larger total WF than pork, which in turn has a larger WF than poultry, but the average global blue and grey WFs are similar across the three meat products. The total water footprint (WF) of pork (expressed as litres per kcal) is two times larger than the WF of pulses and four times larger than the WF of grains (Mekonnen *et al.*, 2011).

Worldwide, with economic development and increasing purchasing power of people, a nutrition transition is taking place in which many people are shifting towards more affluent food consumption patterns containing more animal products. In recent decades, demand for animal products, such as meat, milk and eggs, has increased due to changes in food consumption patterns. In general, the per capita consumption of meat and other animal products increases with average per capita income until it reaches some level of satisfaction. The demand for animal products is predicted to increase. This would require more water. Water consumption and pollution can be assessed using the water footprint concept (Hoekstra *et al.*, 2011), which distinguishes a green WF (consumption of rainwater), a blue WF (consumption of surface and ground water) and a grey WF (pollution of surface or ground water). The production of meat requires and pollutes large amounts of water, particularly for the production of animal feed. On the top, water is required for growing feed, water is needed to mix the animal feed, for maintaining the farm, and for drinking of the animals. In the period 1996-2005, the annual global WF for animal production was 2422 Gm<sup>3</sup> (of which 2112 Gm<sup>3</sup> green, 151 Gm<sup>3</sup> blue and 159 Gm<sup>3</sup> grey). Of this amount, 0.6 Gm<sup>3</sup> of blue water (0.03%) was needed to mix the feed, 27.1 Gm<sup>3</sup> (1.1%) was drinking water and 18.2 Gm<sup>3</sup> (0.75%) was needed for the maintenance of livestock farms. Water for animal products, therefore, mainly refers to water consumed or polluted to produce animal feed.

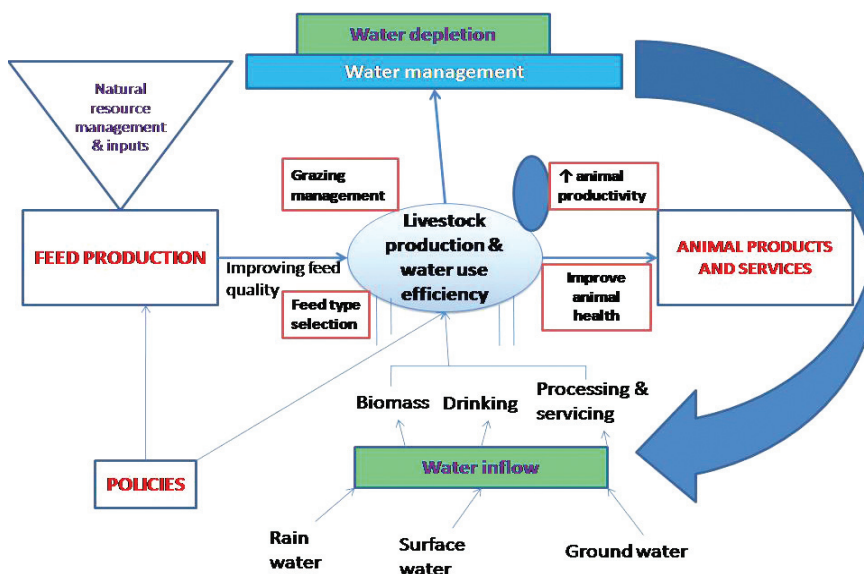
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Livestock keeping is the fastest growing agricultural sector, partly because of increasing and changing demands for adequate, quality and diverse food for people, driven by growing incomes and demographic transitions. Besides the economic benefits, rising livestock production could also deplete water and aggravate water scarcity at local and global scales. The insufficient understanding of livestock-water interactions also led to low livestock productivity, impeded sound decision on resources management and undermined achieving positive returns on investments in agricultural water. Innovative and integrated measures are required to improve water productivity and reverse the growing trends of water scarcity. Livestock water productivity (LWP), which is defined as the ratio of livestock outputs to the amount of water depleted, could be improved through: (i) raising the efficiency of the water inputs by integrating livestock with crop, water and landscape management policies and practices. Improving feed water productivity by maximizing transpiration and minimizing evaporation and other losses is critical; (ii) increasing livestock outputs through improved feed management, veterinary services and introducing system compatible breeds; and (iii) because livestock innovation is a social process, it is not possible to gain LWP improvements unless close attention is paid to policies, institutions and their associated processes. Policies targeting infrastructure development would help livestock keepers secure access to markets, veterinary services and knowledge.

Although water is a renewable natural resource, it has become insufficient at the global level. Unless the current efficiency level of water use can be increased, the trend of water shortages will become more serious. Among agricultural activities, livestock production is mostly considered an intensive water consuming operation although the knowledge and information related to livestock-water interaction appears to be limited in scope.

### **Livestock water productivity in mixed crop–livestock systems**

The presented figure below depicts a conceptual framework for analyzing LWP in mixed crop-livestock systems. The framework accounts for the multiple benefits from livestock, the different water flows involved, and the many factors influencing LWP (not only biophysical but also institutional and socio-economic). The adapted framework for mixed crop–livestock systems in Figure was built upon the original presented by Peden *et al.* (2007) and integrates the production system with hydrology. Thus the conceptual framework offers a way to systematically analyze livestock–water interactions and increase our understanding of water use in mixed farming systems.



Water inflow into the system comprises precipitation, surface water and groundwater. Water is used for biomass production, drinking and processing, and servicing. It allows the system to produce animal outputs by using different feed types and relying on other natural resources and inputs. Animal outputs then contribute to livelihoods and environmental services. This contribution is positive if managed well (e.g., if manure is applied to fields in adequate amounts), but could be negative if managed badly (e.g., if manure and urine contaminate watering points). The water that flows into the system also flows out in one form or another. Transpiration, evaporation, contaminated water, and degraded runoff water all form part of depleted water flows, which cannot be used again within the system. By contrast, non-degraded discharge and deep percolation beneath the root zone might be used by other systems downstream or after recycling.

Using the LWP framework, we identify nine strategies to increase LWP. These include water management, feed type selection, improving feed quality, improving feed water productivity, grazing management, increasing animal productivity, improving animal health, supportive institutions, and enabling policies. The strategies directed at the biophysical components of the farming systems are grouped into three categories related to feed management (improving feed quality, improving feed water productivity, feed type selection, grazing management), water management, and animal management (increasing animal productivity, improving animal health). For each of these, several interventions for LWP improvements are discussed in more detail in the next section.

### Interventions for improving livestock water productivity

Water depletion for feed production varies substantially (Peden *et al.*, 2007; Blummel *et al.*, 2009) and depends on the type of feed used (e.g., grains, forages, concentrates, crop residues, pastures), the use of irrigated water, the climate, and the field management. As

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such, a strategic choice of feed types can clearly increase LWP. In mixed crop-livestock systems, crop residues are an important feed source for ruminants (Devendra and Thomas, 2002). Because crop residues do not consume any additional water, they present a large opportunity to increase feed water productivity and, consequently, LWP (Peden *et al.*, 2007). However, there is a trade-off regarding the maintenance of soil fertility and soil structure, and also, crop residues have little nutritional value (Coleman and Moore, 2003).

### **How improving water use efficiency can improve the farmers' income**

Innovative interventions for improved LWP can be grouped in three categories:

***Feed-related strategies for improving LWP:*** comprise the careful selection of feed types, including crop residues and other waste products; improving the nutritional quality of the feed; optimizing the use of multi-purpose food-feed-timber crops; increasing feed water productivity by appropriate crop and cultivar selection and improved agronomic management; and implementing more sustainable grazing management practices.

***Water management strategies*** for higher LWP consist of water conservation and water harvesting, strategic placement and monitoring of watering points, and the integration of livestock production into irrigation schemes.

***Animal management strategies*** include improving breeds, disease prevention and control, and appropriate animal husbandry, supported by raising awareness among livestock keepers that the same benefit can be obtained from smaller and fewer, but more productive, herds. Designing LWP interventions that benefit the poor requires an understanding of the differentiated access to livestock-related capitals and livelihood strategies of men and women and of different socio-economic groups within local communities (Clement *et al.*, 2010). Livestock often provide an important source of income for women, particularly in mixed crop-livestock systems. Furthermore, in order to facilitate their adoption, technological interventions need to be supported by appropriate policies and institutions (Amede *et al.*, 2011). For example, establishing institutions such as water users' associations, together with policies such as cost recovery for water use, can contribute to improving the efficiency of feed crop irrigation. The important role of informal arrangements in LWP should not be underestimated as these can provide socially acceptable ways for different groups in society to access water (Adams *et al.*, 1997). In communal grazing lands, for example, it is not only vegetation but also water resources that bind herders together, and arrangements are needed to ensure equitable access and sustainable use. Opportunities for the sustainable management of livestock grazing systems in a way that maintains ecosystem services include institutions that enable the management of climate variability, such as early warning and response systems, improved markets, livestock loss insurance schemes and fodder reserves. Other approaches deal with changing the incentive system for keeping large herds, such as payment for environmental services and increasing the level of cost recovery in the use of natural resources, and veterinary services. Such incentive systems require great attention to issues of equity and legitimacy, as they might increase existing or create new social inequities.

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## Other important strategies could be

### Fodder as enhancer of LWP

Fodder trees provide several benefits that enhance livestock water productivity. In addition to providing nutritious fodder, the trees stabilize land, decrease erosion, improve soil structure and fertility, and increase ecosystem stability (Mekoya *et al.*, 2008). Little information is available on the water productivity of different forages, concentrates and supplements (Peden *et al.*, 2007), but adding these nutritive fodder sources to the animal diet improves animal productivity. Dual purpose legumes including cowpea (*Vigna unguiculata*) and lablab (*Lablab purpureus*) (Kabirizi *et al.*, 2007) enhance animal performance and contribute to soil fertility through the fixation of atmospheric nitrogen. Easy to establish and fast growing grasses such as Napier grass (*Pennisetum purpureum*) produce large amounts of feed biomass and have the capacity to stabilize land and gullies, and conserve water. However, due to the high water consumption of Napier grass, causing competition for water with adjacent crops, not all locations are suitable.

### Feed quality

The amount, availability, and nutritive quality of feed influence livestock productivity. The nutritive value of a diet based on crop residues can be improved by adding higher quality feed from leguminous crops or fodder trees or by urea treatment of the residues. The use of dual-purpose genotypes with residues of higher nutritional quality also is very promising in this respect. As overgrazing of pastures often leads to bush encroachment and the prevalence of less palatable species, appropriate grazing management is necessary to obtain high quality feed from these areas.

### Feed water productivity

Feed production is the largest water consumer for livestock production in mixed systems (Peden *et al.*, 2007). Hence interventions that increase feed water productivity will increase LWP. As many feed types are crops or crop residues, most of the recommendations for improving crop water productivity apply also to improving feed water productivity. The feed water productivity of major feeding system type in livestock are displayed in Table 1.

**Table 1. Feed water productivity for different feed types**

S. No.	Feed types	Feed water productivity (kg/m <sup>3</sup> )
1	Cereal grains	0.35-1.10
2	Cereal forages	0.33-2.16
3	Food-feed crops (total biomass)	1.20-4.02
4	Irrigated lucerne	0.80-2.30
5	Pastures	0.34-2.25
6	Semi-arid rangelands	0.15-0.60

**Source:** Ferraria and Sinclair, 1980, Sala *et al.*, 1988, Bonachela *et al.*, 1995, Saeed and El-Nadi, 1997, 1998, Renault and Wallender, 2000, Chapagain and Hoekstra, 2003, Oweis *et al.*, 2004, Singh *et al.*, 2004, Smeal *et al.*, 2005, Nielsen *et al.*, 2006, Gebreselassie *et al.*, 2009, Hailesassie *et al.*, 2011, Van Breugel *et al.*, 2010.



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For small holders, opportunities include reducing unproductive water losses. In general, agronomic measures directed at healthy, vigorously growing crops favor transpirational, productive water losses over unproductive water losses. Alleviating water stress improves water productivity only if other stresses (nutrient deficiencies, weeds, diseases) also are alleviated or removed (Bouman, 2007). In mixed crop–livestock systems, good livestock management contributes to good crop management by providing manure for soil fertility replenishment and animal draught power for timely ploughing.

### **Grazing management**

Pasture and rangeland productivity are improved through grazing management that employs an adaptive stocking density and appropriate herd composition. Such measures positively influence vegetative ground cover, net primary production, and species composition of rangelands. The effects of overgrazing can be minimized and even reversed by restricting or completely banning access to grazing lands (Asefa *et al.*, 2003; Descheemaeker *et al.*, 2010). Pro-active grazing management also requires adequate watering point management. In addition, zero-grazing with cut and carry of grasses can release grazing pressure on pastures. All these measures also result in water conservation. Wherever the regulation of rangeland access is required, strong institutions are essential (Beyene, 2009), which illustrates the links between the biophysical and socio-political–economic domains.

### **Water management**

Water conservation, which involves decreasing the unproductive water losses (runoff, evaporation, conveyance losses, and deep percolation) and increasing water use efficiency of the respective system components, has the potential to increase overall water productivity. Soil and water conservation measures comprise physical structures and vegetation management. Vegetation has significant impacts on infiltration and runoff (Descheemaeker *et al.*, 2010). However, as changes in vegetative cover also influence evaporation and transpiration, the overall impact on the hydrological cycle is complex. Increased vegetative cover results in a higher ratio of productive to unproductive water losses and in higher biomass production, which is potentially used for feed. In water scarce environments, animals often walk long distances to watering points, thus spending substantial energy. Although the amount of water needed for drinking is small in comparison with the amount needed to produce feed, providing this small volume is a strategic choice. It enables animals to access feed and convert it into animal products. Thus it makes a large difference in overall LWP (Peden *et al.*, 2009). Furthermore, the provision of sufficient watering points is instrumental for an optimal distribution of animals making use of available feed and avoiding soil and vegetation degradation and water contamination (Faki *et al.*, 2008).

Irrigation eliminates crop water stress and decreases yield losses from dry spells, thus increasing crop production. Irrigation is relevant for LWP when irrigated crops are used as animal feed, and when other water uses (e.g. livestock drinking) are considered (van Koppen *et al.*, 2006). As such, irrigation development can play an important role in providing alternative watering points. When farmers take their animals with them to



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irrigation schemes, where drinking water is abundant in canals and fodder is provided from crop thinning and grasses, this integration of livestock production and irrigation improves overall system productivity (Ayalneh, 2004; Elzaki, 2005).

### **Animal management**

Low animal productivity in India is manifested in low meat, milk and animal off take rates and low growth and calving rates. One of the reasons is the predominance of local breeds, which were not selected for productive purposes, but for their adaptation to harsh conditions and resistance against prevailing diseases. Therefore, there is still good potential for increasing animal productivity through genetic improvements. In some areas, animal mortality is so high that it seriously undermines all other efforts to increase livestock (water) productivity. High livestock mortality rates are caused by several interrelated factors such as drought and high stocking rates, and the prevalence of animal diseases and inadequate veterinary health services. Diseased or stressed animals lead to lower productivity as they consume feed and water but do not deliver outputs or services as they should. Therefore, investing in veterinary services and disease control to improve animal health is essential in improving LWP.

Animal productivity is also improved if the ratio of feed energy used for maintenance to that used for productive purposes is decreased (Peden *et al.*, 2009). This is achieved through appropriate husbandry, including providing drinking water and shelter. Assessing and partitioning water flows between livestock, crops, other farm components, and the environment at different scales suffer from methodological shortfalls (Cook *et al.*, 2009). Insufficient integration of water and livestock development in the past led to poverty aggravation, environmental degradation, and missed opportunities for investment in both the livestock and water subsectors (Peden *et al.*, 2007). In many countries, development planners have been biased toward the crop sector, and policy makers have usually considered the livestock sector as subsidiary (Scoones and Wolmer, 2006). Moreover, the livestock agenda is usually not integrated in irrigation development, biofuel investments, and reforestation investments. Therefore, policies are needed to facilitate the integration of crop, livestock, land and water management at farm, landscape, and higher levels (Peden *et al.*, 2009).

### **Water productivity-values**

Water productivity of grassland and wetlands (used for grazing) yielded less than 1 kg of biomass per m<sup>3</sup>. Reported values of water productivity for animal feed ranges between 6 and 8 kg per m<sup>3</sup> for irrigated sorghum and 0.1-0.7 kg per m<sup>3</sup> in range lands (Saeed and El-Nadi 1998). Cereal crops, which are major components of the different land uses, were generally in the lower ranges of CWP values and indicative of low yields and poor water management. The question is, what does this imply for potential and actual LWP and ultimately for poor farmers' livelihoods.

Mixed crop–livestock systems are characterized by a strong complementarity in resource use, with outputs from one component being supplied to other components (Devendra and

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Thomas, 2002), such as the improvement of agronomic operations with animal traction or the use of crop residues as feed. Generally speaking, optimal crop-livestock interactions increase productivity and farmers' incomes, while improving system resilience and environmental sustainability (Parthasarathy Rao *et al.*, 2005). Integration of livestock, fed on crop residues or grazing rangelands, typically results in higher water productivity in a farming system as compared to similar systems without livestock.

Livestock provide many different products and services (Thornton and Herrero, 2001; Peden *et al.*, 2007), thus contributing importantly to rural livelihoods. However, livestock productivities in India are generally very low (Parthasarathy Rao *et al.*, 2005; Steinfeld *et al.*, 2006a). This is primarily caused by the low quantity and quality of feed, the predominance of indigenous, low-yielding breeds, the inadequate availability of water resources for drinking and the prevalence of diseases, and high livestock mortality. In addition, Indian smallholders often are constrained by limited access to land and credit, market distortions, lack of technology transfer, and transaction costs.

Agriculture will remain the largest water user, accounting for about 75% of human water use (Wallace, 2000). The current over-exploitation of limited water resources in crop-livestock systems is already resulting in falling groundwater levels, decreasing river flows, worsening water pollution, declining lake levels and deteriorating wetland systems (Rockstrom and Barron, 2007). With increasing demands for animal products, along with increasing global water scarcity and competition for water, there is a pressing need to increase livestock production, without depleting more water, and while safeguarding the environment. Improving water productivity in livestock production systems can benefit both the environment and people's livelihoods (Cook *et al.*, 2009). However, according to Peden *et al.* (2009), better understanding of the livestock-water interactions is still needed to improve livestock water productivity.

### **Livestock water interaction**

Livestock production systems impact the environment. Global environmental evidence has led several authors (Steinfeld *et al.*, 2006a; Costales *et al.*, 2006) to conclude that the livestock sector has a strongly negative impact on water depletion and pollution. However, caution is needed: large differences in water use exist between industrial livestock production systems and smallholder, mixed crop-livestock systems (Peden *et al.*, 2009). Whereas industrial systems may lead to soil and water contamination from manure and wastewater mismanagement and excessive use of chemicals, these issues are (not yet) problematic in smallholder, low-input farming systems. Livestock convert water resources into high value goods and services. Animals derive their water from different sources (McGregor, 2004), such as water directly consumed by drinking and water consumption through feed intake. The amount of drinking water used varies from 201 to 501 litres per day per tropical livestock unit (TLU, 250 kg bodyweight), and depends on various factors related to the animal, the feed, and environmental conditions (Gigar-Reverdin and Gihad, 1991).

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Although water for livestock drinking and servicing is the most obvious water use in livestock production systems, it constitutes only a minor part of total water consumption (Peden *et al.*, 2009). The major water depletion by livestock is related to the transpiration of water for feed production, which is generally about 50–100 times the amount needed for drinking (Gebreselassie *et al.*, 2009). Livestock systems depending on grain based feeds, as is the case in the developed world, use more water than systems relying on crop residues and pasture lands. In many of the mixed farming systems in SSA, no extra water is allocated to meet the animal feed requirements. Livestock keeping has important impacts on water resources at the watershed and landscape scales (Amede *et al.*, 2011). Livestock grazing affects the hydrological response of pastures and rangelands and may result in soil and vegetation degradation (Descheemaeker *et al.*, 2010). Grazing pressure on vegetation and the trampling effect of livestock are especially notable around watering points, where land degradation can be severe (Brits *et al.*, 2002). Moreover, if watering points are not well protected or managed, water contamination due to the inflow of faecal excretions can make the water unsuitable for other productive uses (Wilson, 2007).

### **Reducing postharvest losses**

Approximately 1.3 billion t of food are lost or wasted annually, which is roughly one third of the human food produced (Gustavsson *et al.*, 2011). These losses occur mostly at the postharvest and processing levels in developing countries, and at the retail and consumer levels in industrialized countries. However, the per capita food losses in developing and industrialized countries are remarkably comparable. In sub-Saharan Africa, postharvest grain losses can amount to 10–20% of the production (World Bank *et al.*, 2005), which means that 10–20% of the inputs, including water, are wasted as well. Therefore, reducing postharvest losses could be an effective way of achieving higher productivity (including water productivity) in agriculture (Clarke, 2004). Many promising practices and technologies are available for reducing postharvest losses, including improved handling, storage and pest control. Incentives and public programmes are also needed to raise awareness and promote societal change in behaviour towards both a healthy diet and food waste.

### **Key principles for improving water productivity in livestock production**

The key principles for improving water productivity at field, farm and basin level, which apply regardless of whether the crop is grown under rainfed or irrigated conditions, are: (i) increase the marketable yield of the crop for each unit of water transpired by it; (ii) reduce all outflows (e.g. drainage, seepage and percolation), including evaporative outflows other than the crop stomatal transpiration; and (iii) increase the effective use of rainfall, stored water, and water of marginal quality.

Improved practices at field level relate to changes in crop, soil and water management. They include: selecting appropriate crops and cultivars; planting methods (e.g. on raised beds); minimum tillage; timely irrigation to synchronize water application with the most sensitive growing periods; nutrient management; drip irrigation; and improved drainage for water table control. Water depletion occurs when water evaporates from moist soil, from

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puddles between rows and before crop establishment. All cultural and agronomic practices that reduce these losses, such as different row spacings and the application of mulches, improve water productivity. The irrigation method also affects these evaporative losses. Drip irrigation causes much less soil wetting than sprinkler irrigation. The significance of soil improvement in enhancing water productivity is often ignored. However, integrated crop and resource management practices, such as improved nutrient management, can increase water productivity by raising the yield proportionally more than it increases evapotranspiration. This principle applies to both irrigated and rainfed agriculture. Integrated weed and integrated pest management have also contributed effectively to yield increases. Crop-livestock systems are mostly rainfall-dependent and based on fragmented marginal lands that are vulnerable to soil erosion, drought and variable weather conditions. The threat of water scarcity in these systems is real, due to expanding demand for food and feed, climate variability and inappropriate land use.

According to recent estimates, farming, industrial and urban needs in developing countries will increase water demand by 40% by 2030. Water shortage is expected to be severe in areas where the amount of rainfall will decrease due to climate change. The lack of capacity of communities living in drought-prone regions to respond to market opportunities, climatic variability and associated water scarcity also results from very low water storage facilities, poverty and limited institutional capacities to efficiently manage the available water resources at local, national and basin scales. Strategies and policies to reduce rural poverty should not only target increasing food production but should also emphasize improving water productivity at farm, landscape, sub-basin and higher levels. In drought-prone rural areas, an increase of 1% in crop water productivity makes available at least an extra 24 litres of water a day per person. Moreover, farming systems with efficient use of water resources are commonly responsive to external and internal drivers of change.

## References

- Adams, W.M., Watson, E.E. and Mutiso, S.K. 1997. Water, rules and gender: water rights in an indigenous irrigation system, Marakwett, Kenya. *Development and Change* 28: 707-730.
- Amede, T., Tarawali, S. and Peden, D. 2011. Improving water productivity in crop livestock systems of drought-prone regions. *Expl. Agric.* 47(S1): 1-5. doi:10.1017/S0014479710001031
- Asefa, D.T., Oba, G., Weladji, R.B. and Colman, J.E. 2003. An assessment of restoration of biodiversity in degraded high mountain grazing lands in northern Ethiopia. *Land Degradation and Development* 14: 25-38.
- Ayalneh, W. 2004. Socio economic and environmental impact assessment of community based small-scale irrigation in the Upper Awash Basin: A case study of four community based irrigation schemes. MSc Thesis. Addis Ababa, Ethiopia: Addis Ababa University, School of Graduate Studies, Environmental Science. Available at <http://www.iwmi.cgiar.org/Assessment/files/pdf/PhDThesis/Wagnew-thesis.pdf>
- Beyene, F. 2009. Exploring incentives for rangeland enclosures among pastoral and agropastoral households in eastern Ethiopia. 19: 494-502.

- 
- Blummel, M., Samad, M. and Amede, T. 2009. Opportunities and limitations of food-feed crops for livestock feeding and implications for livestock water productivity. *The Rangeland Journal* 31: 207-213.
- Bonachela, S., Orgaz, F. and Fereres, E. 1995. Winter cereals grown for grain and for the dual purpose of forage plus grain II. Water use and water-use efficiency. *Field Crops Research* 44, 13–24. doi:10.1016/0378-4290(95)00046-3.
- Bouman, B. 2007. A conceptual framework for the improvement of crop water productivity at different spatial scales. *Agricultural Systems* 93: 43-60.
- Brits, J., van Rooyen, M.W. and van Rooyen, N. 2002. Ecological impact of large herbivores on the woody vegetation at selected watering points on the eastern basaltic soils in the Kruger National Park. *African Journal of Ecology* 40: 53-60.
- Chapagain, A. and Hoekstra, A. 2003. Virtual Water Trade: A Quantification of Virtual Water Flows between Nations in Relation to International Trade of Livestock and Livestock Products. In: 'Virtual Water Trade'. Proceedings of the International Expert Meeting on Virtual Water Trade, Value of Water Research Report Series 12. (Ed. A. Y. Hoekstra) pp. 49-76. (United Nations Educational, Scientific and Cultural Organization, Institute for Water Education:Delft.)
- Clarke, B. 2004. High-hopes for Post-harvest. A New Look at Village-scale Crop Processing. FAO Diversification Booklet 4, Agricultural Support Systems Division, Food and Agriculture Organization of the United Nations, Rome.
- Clement, F., Haileslassie, A., Ishaq, S., Blummel, M., Murty, M.V.R., Samad, M., Dey, S., Das, H. and Khan, M.A. 2010. Enhancing water productivity for poverty alleviation: role of capitals and institutions in the Ganga Basin. *Experimental Agriculture* 47 (Suppl. 1): 133–151.
- Coleman, S.W. and Moore, J.E. 2003. Feed quality and animal performance. *Field Crops Research* 84: 17-29.
- Cook, S., Andersson, M. and Fisher, M. 2009. Assessing the significance of livestock water use in basins. *The Rangeland Journal* 31: 44-57.
- Costales, A., Gerber, P. and Steinfeld, H. 2006. 'Underneath the livestock revolution.' Livestock report 2006. (Food and Agriculture Organization: Rome.)
- Descheemaeker, K., Amede, T., Haileslassie, A. and Bossio, D. 2010. Analysis of gaps and possible interventions for improving water productivity in crop-livestock systems of Ethiopia. *Experimental Agriculture* 47 (Suppl. 1): 21-38.
- Devendra, C. and Thomas, D. 2002. Crop-animal interactions in mixed farming systems in Asia. *Agricultural Systems* 71: 27-40.
- Elzaki, R. 2005. The feasibility of integration of livestock production in irrigated agriculture in Sudan: case study: The Gezira scheme. PhD Thesis. University of Giessen. Department of Project and Regional Planning.
- Faki, H., El-Dukheri, I., Mekki, M. and Peden, D. 2008. Opportunities for increasing livestock water productivity in Sudan. In: *Fighting poverty through sustainable water use: Volume II*, eds. Humphreys, E.; Bayot, R. S.; van Brakel, M.; Gichuki, F. N.; Svendsen, M.; Wester, P.; Huber-Lee, A.; Cook, S.; Douthwaite, B.; Hoanh, C. T.; Johnson, N.; Nguyen-Khoa, S.; Vidal, A.; MacIntyre, I.; MacIntyre, R. Proceedings of the CGIAR Challenge Program on Water and Food 2<sup>nd</sup> International Forum on Water and Food, Addis Ababa, Ethiopia, November 10-14, 2008. CGIAR Challenge Program on Water and Food, Colombo, Sri Lanka. 297 pp.
-

- 
- Ferraris, R. and Sinclair, B. 1980. Factors affecting the growth of *Pennisetum purpureum* in the wet Tropics, II. Uninterrupted Growth. *Australian Journal of Agricultural Research* 31(5): 915-925.
- Gebreselassie, S., Peden, D., Hailelassie, A. and Mpairwe, D. 2009. Factors affecting livestock water productivity: Animal scale analysis using previous cattle feeding trials in Ethiopia. *The Rangeland Journal* 31, 81-96.
- Gigar-Reverdin, S. and Gihad, E.A. 1991. Water metabolism and intake in goats. In: 'Goat nutrition'. (Ed. Morand -Fehr) pp. 37–45. (Pudoc: Wageningen.)
- Gustavsson, J., Cederberg, C., Sonesson, U., van Otterdijk, R. and Meybeck, A. (2011). *Global Food Losses and Food Waste*. Food and Agriculture Organization of the United Nations, Rome.
- Hailelassie, A., Blümmel, M., Clement, F., Descheemaeker, K., Amede, T. Samireddypalle, A., Acharya, N.S., Radha, A.V., Ishaq, S., Samad, M., Murty, M.V.R. and Khan, M.A. 2011. Assessment of the livestock-feed and water nexus across a mixed crop-livestock system's intensification gradient: an example from the Indo-Ganga Basin. *Experimental Agriculture* 47 (Suppl. 1): 113-132.
- Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M. and Mekonnen, M.M. 2011. *The Water Footprint Assessment Manual: Setting the Global Standard*. London, Earthscan.
- Kabirizi, J., Mpairwe, D. and Mutetikka, D. 2007. The Effect of Integrating Forage Legumes in Smallholder Crop/Livestock Farming Systems on Food, Fodder and Animal Performance. Paper presented at Tropentag, October 9-11, 2007, Witzenhausen, Germany.
- McGregor, B.A. 2004. Water quality and provision for goats. Report Phase 2. A report for the Rural Industries Research and Development Corporation. RIRDC publication no. 04/036, project no. DAV 202A.
- Mekonnen, S., Descheemaeker, K., Tolera, A. and Amede, T. 2011. Livestock water productivity in a water stressed environment in northern Ethiopia. *Experimental Agriculture* 47(Supplement 1): 85-98.
- Mekoya, A. Oosting, S. Fernandez-Rivera, S. and van der Zijpp, A.J. 2008. Multipurpose fodder trees in the Ethiopian highlands: Farmers' preference and relationship of indigenous knowledge of feed value with laboratory indicators. *Agricultural Systems* 96: 184-194.
- Navarro, T. Alados, C. and Cabezudo, B. 2006. Changes in plant functional types in response to goat and sheep grazing in two semi-arid shrub lands of SE Spain. *Journal of Arid Environments* 64: 298-322.
- Negassa, A. and Jabbar, M. 2008. *Livestock Ownership, Commercial Off-take Rates and Their Determinants in Ethiopia*. Research Report 9. Nairobi, Kenya: International Livestock Research Institute.
- Nielsen, D.C., Vigil, M.F. and Benjamin, J.G. 2006. Forage yield response to water use for dryland corn, millet, and triticale in the Central Great Plains. *Agronomy Journal* 98, 992–998. doi:10.2134/agronj2005.0356
- Oweis, T., Hachum, A. and Pala, M. 2004. Water use efficiency of winter-sown chickpea under supplemental irrigation in a Mediterranean environment. *Agricultural Water Management* 66, 163-179. doi:10.1016/j.agwat.2003.10.006
- Parthasarathy Rao P., BIRTHAL, P.S., and Ndjunga, J. 2005. *Crop–Livestock Economies in the Semi-Arid Tropics: Facts, Trends and Outlook*. (International Crops Research Institute for Semi -Arid Tropics: Patancheru.)
-



- 
- Peden, D., Tadesse, G., and Misra, A.K. 2007. Water and livestock for human development. In: 'Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture'. (Ed. D. Molden.) pp. 485-514. (Earthscan: London, and the International Water Management Institute: Colombo).
- Peden, D., Tadesse, G. and Hailelassie, A. 2009. Livestock water productivity: Implications for sub-Saharan Africa. *The Rangeland Journal* 31:187-193.
- Renault, D. and Wallendar, W. 2000. Nutritional water productivity and diets. *Agricultural water management* 45: 275-296.
- Rockström, J. and Barron, J. 2007. Water productivity in rainfed systems: overview of challenges and analysis of opportunities in water scarcity prone savannahs. *Irrigation Science* 25, 299-311.
- Saeed, I.A.M. and El-Nadi, A.H. 1997. Irrigation effects on the growth, yield and water use efficiency of alfalfa. *Irrigation Science* 17: 63-68. doi:10.1007/s002710050023.
- Saeed, I.A.M. and El-Nadi, A.H. 1998. Forage sorghum yield and water use efficiency under variable irrigation. *Irrigation Science* 18: 67-71. doi:10.1007/s002710050046.
- Sala, O.E., Parton, W.J., Joyce, L.A. and Lauenroth, W.K. 1988. Primary production of the central grasslands of the United States. *Ecology* 69: 40-45. doi:10.2307/1943158.
- Scoones, I. and Wolmer, W. 2006. Livestock, disease, trade and markets: policy choices for the livestock sector in Africa. IDS Working Paper 269. (Institute of Development Studies: Brighton.)
- Singh, O., Sharma, A., Singh, R. and Shah, T. 2004. Virtual water trade in Dairy Economy. *Irrigation water productivity in Gujarat. Economical and Political Weekly* 39, 3492-3497.
- Smeal, D., O'Neill, M.K. and Arnold, R.N. 2005. Forage production of cool season pasture grasses as related to irrigation. *Agricultural Water Management* 76: 224-236. doi:10.1016/j.agwat.2005.01.014.
- Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M. and de Haan, C. 2006. Livestock's long shadow. Environmental issues and options. (Food and Agriculture Organization: Rome).
- Thornton, P. and Herrero, M. 2001. Integrated crop-livestock simulation models for scenario analysis and impact assessment. *Agricultural Systems* 70, 581-602. doi:10.1016/S0308-521X(01)00060-9.
- Van Breugel, P., Herrero, M., van de Steeg, J. and Peden, D. (2010). Livestock water use and productivity in the Nile Basin. *Ecosystems* 13, 205-221. doi:10.1007/s10021-009-9311-z.
- van Koppen, B., Moriarty, P. and Boelee, E. 2006. Multiple-use Water Services to Advance the Millennium Development Goals. IWMI, Colombo, Sri Lanka, 44 p. (IWMI Research Report 98).
- Wallace, J. (2000). Increasing agricultural water use efficiency to meet future food production. *Agriculture, Ecosystems and Environment* 82: 105-119.
- Wilson, T. (2007). Perceptions, practices, principles and policies in provision of livestock water in Africa. *Agricultural Water Management* 90: 1-12.
- World Bank (2005). Investments in agricultural water for poverty reduction and economic growth in Sub-Saharan Africa. Synthesis report. 90pp.
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# **Livestock Integrated Farming Systems: A Boon to Dryland Farmers**

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Climatic related risks are expected to rise in near future as global average surface temperature is predicted to increase 1.8 to 4.0° C by 2100 and would results in variety of adverse consequences on agriculture and allied sectors. It was causing immediate danger for human societies through alterations in food production and livelihoods systems. The demand and supply chain will force changes in our farming systems to meet their desire for more “sustainable” food and feed production. Resource depletion and climate change in future will gradually drive the farmers towards more integrated and sustainable farming systems. Integrated farming system (IFS) refers to the efficient management of available resources in an integrated manner for sustainable agri and allied sector production which may include either livestock or poultry or fish components in addition to a crop or orchard or cropping system. Less valuable products of one component serve as a valuable resource for the other. Integrated crop–livestock farming systems comprise a large proportion of farming systems in India and producing 109 mmt milk and 6.8 mmt meat. These systems have been intensified over the years is mainly due to demographic pressure leading to an increase in demand for crop and livestock products. Farming systems that successfully integrate crop and livestock enterprises stand to gain many benefits that can have a direct impact on whole farm production. IFS increase the diversity, in addition to environmental sustainability and provide opportunities for increasing overall production and economics of farming especially in dryland areas.

Integration of livestock with crop or cropping systems helps in many ways to the farmers. It could be agronomic- management of soil fertility through organic resources and animal power to agricultural operations or it could be more economical –nutrient flow of feed and fodder to the animals through crops residues and byproducts from agriculture produce. Livestock integrated farming system with efficient resource use lead to high and sustained production levels, while minimizing the negative impacts of intensive farming and conserving natural ecosystem. Enhancing natural biological processes above and below the ground, would (a) Reduces erosion; (b) Increases crop yields, soil biological activity and nutrient recycling; (c) Intensifies land use, improving profits; and (d) Can therefore help reduce poverty and malnutrition and strengthen environmental sustainability (Gupta *et al.*, 2012). Livestock plays a significant role in Indian farmers’ economy and which can be gauged from the fact that 20.5 million farming families, cultivating 159.7 million hectare

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area, rearing 133.3 million milch animals (cattle and buffaloes) and 200.3 million small ruminants (sheep and goat) producing milk (163.7 million tons), meat (8.89 million tons) and contributing around 4.11% GDP of the country and 25.6% of its agricultural GSDP. The value of milk group and meat group at current prices was Rs 4,06,035 crores in 2013-14. The interface between the two components i.e., crop and livestock needs certain extent of constant compromise in use of resources. But, from a natural resource management and ultimately economic and the broader agriculture sustainability perspective our understanding of spatially mixing crop and livestock based integrated farming system will be imperative and vital not only in dryland areas, but across the different agro-ecological zones of the country.

Scenario of feed and fodder resources and demand in the country explicitly indicates the necessity of efficient utilization of available resources from crop and cropping systems for sustainability of not only farmer's income but also the productivity of livestock. Cropped area under fodder production is about 11 million ha (6.25%). Only about half of the annual fodder requirement is met from the cultivated fodder and crop residues. By 2020, Indian livestock need 526 million tons of dry matter, 56 million tons of concentrate feed and 855 million tons of green fodder (as fed) for optimum productivity (Dikshit and Birthal, 2010). At present the country faces a net deficit of 61.1% green fodder, 21.9% dry crop residues and 64% concentrate feeds.

### **Scope and prospects of the integrated farming systems with livestock**

India has 228 million ha (69%) of the total geographical area (about 328 million ha) is under dry lands (arid, semi-arid and dry sub-humid) and is affected by the unpredictable nature of rainfall during the monsoon and aberrant weather situations like long gaps in rainfall, delayed start of monsoon and early cessation of rains leading to ambiguity in production, low yields per unit area and low income. Further, these areas incidentally are highly populated which makes the people vulnerable to environmental stress and impacts livelihoods directly. In these areas, agro-ecologically sustainable IFS models with different species of livestock including poultry and fishery has a lot of scope in enhancing the productivity and profitability, minimizing risk and improving the livelihoods of millions of rural population dependent on dryland agriculture. Livestock has always provided the much needed resilience to dryland farming in most drought-prone regions of the country. Livestock serve not only as an effective enterprise in terms of converting the cereal crop residues into nutritious protein (milk or meat), but also recycles the nutrients to the soil through farm yard manure for sustainable agricultural production. In the distressed and resource-poor dryland agro-eco systems, the role of livestock is all the more important since they provide year-round liquidity that meets the domestic and farm needs of the agriculturists. Livestock builds resilience to IFS by providing daily income through sale of livestock products (milk, meat and eggs), annual income through sale of manure and as liquid asset through sale of livestock and also provides draft animal power in agriculture especially for farmers with less

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than one hectare farm size. Increasing demand for livestock products further necessitates more and more livestock based farming systems and this can be evidenced from increasing in per capita milk (91 to 115 kg/year), meat (2.8 to 5.4 kg/year), eggs (23 to 53 number per year) and fish (4.0 to 6.2 kg/year) consumption of rural and urban households during 1987-88 to 2009-10 in India (NCAER, 2014). Further, the future demand for the available farm yard manure as organic fertilizer under national programme for organic production seems to be immense and plays a vital role in reclamation of soil organic carbon in poor dryland soils for enhancing the productivity of crops.

Considering the resource base available in the country, prospects are much better for livestock than any other component for integration in cropping systems. The extent of land available for grazing like forest area, fallows, wastelands and specified grazing / pasture lands etc., forms the major source of forage for both small and large ruminants in rural areas. Dry fodder resources like cereals and millets in addition to the groundnut and pulses grown by farmers serves as source of roughages in the form of stover, straw, haulms and other materials and forms the major portion of dry fodder for livestock. Green fodder resources like annual (sorghum, maize, berseem, Lucerne, cow pea, horsegram etc) and perennial fodder (Co-3, Co-4, APBN-1 etc.) grown by farmers in cultivated lands serves as source of green fodder for livestock.

Types of integrated livestock based farming systems and domain areas: There are many integrated farming systems do exist in different agro-ecological regions under rural conditions. Integrated farming system comprising enterprises viz. field and horticultural crops, poultry, fishery (0.20 ha) and apiary (5 bee hive boxes) in 0.6 ha area in Chintapalli of high altitude and tribal zone of Andhra Pradesh recorded a net income of Rs.29,102 and B:C ratio of 1.83 with productivity of 14.40 (t ha<sup>-1</sup>) and 464 man days/ha/year over arable cropping returns (Rs.14500/ha) and B:C ratio (1.47) with less productivity (7.50 t ha<sup>-1</sup>) (Sekhar *et al.*, 2014). Integration of field crops (Rice) + poultry + fish + horticultural crop (banana) resulted in highest system productivity (14.90 t ha<sup>-1</sup>) in terms of rice grain equivalent yields. The integrated farming system besides generating higher productivity, also producing sufficient food, fruits, vegetables etc., to the farm families. This system recorded 99.3% more productivity over cropping alone. Similarly, fish + horticulture + apiary system recorded 96% higher productivity (14.40 t ha<sup>-1</sup>) than rice-rice alone. Paddy-fish-horticultural system gave 88.3% higher productivity over conventional cropping. Several IFS models like (A) Conventional cropping; (B) crop + poultry (20) + goat (4); (C) crop + poultry (20) + goat (4) + dairy (1); (D) crop + poultry (20) + goat (4) + sheep (6); and (E) crop + poultry (20) + goat (4) + sheep (6) + dairy (1) were studied. Among the models examined, model (E) recorded a maximum net income of Rs 52794/ha, with maximum employment generation (389 mandays/ha/year) (Solaiappan *et al.*, 2007). Some suitable integrated livestock based farming systems for different agro-ecological regions of Andhra Pradesh are

**Crop:** livestock integrated farming system: In this type of integration, mostly dairy animals like cows and buffaloes are integrated with cropping system for milk production and is more

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common in rural India. Residues from the *kharif* crops like paddy, sorghum, groundnut etc., forms the basal diet for the dairy animals and these animals are supplemented with green fodder from grazing or cultivated lands along with household or purchased bran and or cake during milking. Depending on the availability of crop residues and also purchasing capability of the farmers, the type and number of milch animals varies from farmer to farmer. This type of integration is mostly market driven and more common in peri-urban than remote areas and is suitable for all the agro-climatic zones depending on the demand and market for the sale of milk. In order to exploit full potential of dairy animals reared under these systems, incentives like subsidized fodder seed, concentrate mixture, mineral mixture, silage bags, shelters for storing crop residues etc., are required. Integrated farming system has a combination of crop and livestock enterprises and in some cases may include combinations of aquaculture and trees. It is a component of farming systems, which takes into account the concepts of minimizing risk, increasing total production and profits by lowering external inputs through recycling and improving the utilization of organic wastes and crop residues. It provides a steady and stable income, rejuvenation/amelioration of the system's productivity and also improves space utilization and increase productivity per unit area.

A long-term experiment with farming system modules on micro-watershed basis in a watershed (13,964 m<sup>2</sup> area) at HRF with a total of 23 crops (4 field crops, 9 vegetables, 2 fruit crops, 3 grasses/fodder, 2 tree crops, 2 bush crops and 1 essential oil yielding crop) were studied. The main advantage of this FSM was production of fodder from diverse sources and this was integrated with ram lamb fattening. The available fodder would meet the nutritional requirements of 10 ram lambs for a period of 5-6 months. Through this system, 1.2-1.5 t of organic fertilizer in the form of sheep faeces can be produced to improve fertility of soil. An additional income of 12000-15000 would be possible with integration of small ruminants through lamb fattening in addition to the income from crop production.



**Crop-livestock-poultry:** Where in integrated farming system livestock like cattle or buffaloes or small ruminants especially sheep are integrated with crop production. Benefits of integration are synergistic rather than additive. Crop and livestock components may benefit to varying degrees to the overall profitability of the system. Crop residues, otherwise which goes as waste form the feed for livestock along with natural and cultivated forage and produces primarily milk or meat in addition to the farm yard manure for soil application. Integrated farming system offer a pragmatic solution to meet the increasing demand for food, diversification in food hab-

its and stabilizing the income thus improving the nutrition of the small-scale farmers with limited resources. Further, integration of different farm components i.e., crops + horticultural crops (fruits & vegetables) and livestock along with vermi-composting as value addition practice has been found to have maximum gross and net returns with maximum net returns of Rs. 42,610 (51.7%) from livestock, including vermin-compost (AI-CRP-IFS,2013). Local non-descriptive



cows and buffaloes are recommended for marginal and small farmers who have limited feed, fodder and financial resources, where as graded buffaloes and crossbred cows are recommended for medium and large farmers who have sufficient feed, fodder resources along with supplement feed purchasing capacity. Small ruminant (sheep and goat) production is more in resource-poor areas (Hanumantha Rao 1994) and it is not high among resource-poor farmers. This is because of the need of more grazing resources like forest/fallow/CPR lands for rearing small ruminants and this can be integrated with coarse cereal crop production systems. Inclusion of 10-20 synthetic poultry breeds like Giriraja/ Vanaraja/ Gramapriya/ Rajasree etc., at backyard with available food grain wastes/ grain by-products (broken rice/rice bran etc.) from the cropping system will also provide additional income through sale of eggs and chicken. All these types of systems are suitable for the scarce rainfall zone where the rainfall is 500-750 mm.

Integration of high yielding graded Murrah buffaloes and crossbred cows with cropping systems should be recommended for the areas having some irrigation facilities and or receiving above 1000mm rain fall. These areas generally produce surplus crop residues besides allocation of some cultivated land for fodder crops and purchase of feed supplements. In these systems inclusion of 10-20 synthetic poultry breeds like Giriraja/Vanaraja/ Gramapriya/Rajasree etc., at backyard will further boost the income of the farmers.

***Crop-livestock-poultry-fishery integrated farming system:*** These type of systems are mostly suitable for high rainfall areas, where paddy is cultivated both in *Kharif* and *Rabi* seasons. Cows and or buffaloes are maintained at backyard with crop residues and supplements. Fish is reared in farm ponds and poultry is maintained in cages over the pond with grain and bran supplementation. The droppings of poultry serve as feed for the fish in the pond. These types of systems are suitable for the areas where assured canal irrigation is available. These integrated systems are also possible in dryland areas with little modifications like rearing poultry at backyard and raising yearlings for 4-5 months in water harvesting farm ponds developed under watershed for lifesaving irrigation to the crops. These systems are most suitable for North-Eastern states.



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**Silvo-pastoral systems:** It is an efficient and integrated land use management system of agricultural crops, tree fodder species and or livestock simultaneously on the same unit of land which results in an increase of overall production. Inter spaces between fodder trees species (*Leucaena leucocephala*) are utilized for cultivation of grasses and grass legume mixtures (*Cenchrus ciliaris* and *Stylosanthes hamata* or *scabra*), which provides a two tier grazing under in situ. One year after establishment of fodder species the small ruminants are allowed to graze. During rainy seasons the animals prefer to graze green grass, but during dry seasons when there is no blade of grass available, they utilize foliage of the trees along with crop residues. It involves interaction of woody perennials ecologically and economically with the crops and or livestock. This type of systems provide Rs.25000-30000 income per ha (Ramana, *et al.*, 2000) and helps in reclamation of soil in waste lands and are more suitable for rearing small ruminants (10-12 animals/ha) in degraded waste lands under dryland conditions in Scarce rainfall zone.

**Horti-pastoral systems:** In these systems, the inter tree spaces in the mango/lemon/sweet orange orchards are utilized for cultivation of grasses and grass legume mixtures (*Cenchrus ciliaris* and *Stylosanthes hamata* or *scabra*) along with one side boundary plantation of fodder trees species (*Leucaena leucocephala*). One year after establishment of fodder species, 2-3 lambs (mostly ram lambs) per ha are introduced and reared for 5 months (August to December). Cultivated fodder and weeds serve as feed for the animals. Integration of lambs provide Rs.4000-5000 additional income per ha through sale of animals, control weeds by grazing/browsing and also improve soil fertility through faeces and urine (Ramana, 2008 and Ramana *et al.*, 2011). These types of systems are suitable for areas where orchards exist. A number of factors need to be considered while integrating livestock with crop and or orchard farming. It includes the type of livestock (cattle/buffaloes/sheep/goat/poultry), stocking density, palatable and nutritious feed supply, possible damage to the crops/plants and security. If goat is integrated with orchards, it is recommended that the lowermost branches of the trees should be above 1 meter from the ground. It should be emphasized too that livestock integration alone will not ensure successful harvest from crop/orchard farms. Many factors, including climate, farming practices, cost of inputs and market etc., impacts production and profitability.

### **Prerequisites or support systems for integrated livestock based farming systems**

Livestock-crop relationship could be competitive or complementary depending on the level of harmonization of resources use and also availability such as land, labour, capital etc. Livestock density is much higher in most of the dryland areas compared to their carrying capacity and most of the traditional intercropping systems are rapidly transformed to intensive commercial mono cropping and affected fodder and feed security of livestock in the last decade. Further, distribution of waste lands and shrinking of CPRs reduces the land available for growth of natural and cultivated pasture land or grain and fodder producing crops thus creating competition between crops, animals and humans for natural resources.

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Collection of available crop residues and or green fodder and proper preservation in the form of hay or silage and its subsequent utilization in efficient manner along with byproducts of grains plays a vital role in enhancing productivity of livestock component and its contribution to the overall profitability of integrated farming system. Further, continuous supply of green fodder in the form of forage or silage is prerequisite for profitable livestock based integrated farming systems.



Hence, the farmer should have some land for cultivation of fodder. Infra structure like chaff cutters, silage bags and supplements like mineral mixture and concentrate mixture should be made available in the village for the farmers on subsidy. Establishment of community operated complete feed mills at each 4-5 cluster of villages covering a radius of 5-10km will further help the farmers in efficient utilization of unconventional crop residues like red gram stalks as feed for livestock.

The small size of backyard poultry flocks confined overnight for manure collection limits their impact in even a small fishpond. Moreover, variations in flock size and structure greatly affect actual waste availability throughout the year. Increasing flock size so that more waste is available for fertilizing fishponds requires improved availability of supplementary feed and a reduction in mortalities, particularly among young poultry. Hence, some infrastructure facilities for brooding, vaccination seems to be essential along with supply of poultry feed on subsidized rates for integration of poultry and fishery in wetland cropping systems. Least-cost production techniques that depend on using several combinations of ingredients, rather than a single high-cost compounded feed, is a relevant strategy for both livestock and fish production. Assuming 50 households in each village are small and marginal, an amount of Rs.5-10 lakhs for infra structure and 20-25 lakhs for supplements would be required as additional budget for upscaling the livestock based integrated farming system.

### **Probable scenario in the next 15-20 years with the integrated livestock based farming systems**

Demographic patterns, especially rapid developing era and mounting resource demands which, in the cases of food and natural resources like land and water, might lead to severe scarcities. These trends, which are virtually certain, exist today, but during the next 15-20 years they will gain a great deal of momentum. Recently introduced National Livestock Policy, aims at increasing livestock productivity and production in a sustainable manner while protecting the environment, preserving animal bio-diversity, ensuring bio-security and farmers' livelihood. Further, under 12<sup>th</sup> plan proposal, many initiatives on fodder development in the country like mapping of ecologically sensitive pastures and development of rehabilitation packages, rehabilitation and productivity enhancement of degraded grazing



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lands, promoting fodder species under agro-forestry initiatives, developing seed/ germ-plasm banks/ nurseries of native species for rehabilitation of grazing lands, developing fodder storage/ value addition facilities, capacity building of Managers/ Community Groups have been introduced. National grazing-cum-fodder and pasture management policy and national centre of excellence (CoE) for fodder and pasture land management have been proposed and emphasized for encouragement and establishment of cooperatives for fodder and pasture management and these would enhance the availability of fodder for livestock. Hence, integrated livestock based farming system would certainly reduce the competition and demand for natural resources and produce more food for ever growing population in the country. These integrated systems would increase efficiency of production systems and reduce pressure on natural resources and ultimately result in sustainable agriculture with assured food and livelihood security in future. It would increase the income by 25-30% and provide livelihoods to more than 60% of population and also contributes to soil reclamation and organic food production.

## **Conclusions**

Integrated farming system models suitable to the agro-climatic zones will vary with location depending on natural resources (grazing lands, water, rainfall and other climatic factors, soil types) and crop residues, byproducts and forage availability and market demand for the produce. Integrated farming system with livestock absolutely helps in recycling and improving utilization of organic wastes and crop residues and lowers external input requirements, minimizes risk, increases total production and profit. Livestock based integrated farming systems interact eco-biologically, in space and time, are mutually accommodative and depend on each other in additive fashion and results in more efficient use of their marginal small holdings with less external inputs, improve their economic gains substantially and pays path towards achieving a more sustainable agricultural food production systems in drylands.

## **References**

- AICRP-IFS, 2013 AICRP on IFS. 2013. Annual Report 2012-13. Project Directorate for Farming Systems Research (Indian Council of Agricultural Research), Modipuram, Meerut, 110p.
- Dikshit, A.K and BIRTHAL, P.S. 2010. India's livestock feed demand: Estimates and projections. *Agricultural economics research review*, 23:15-28.
- Gupta, Vinod., Pradeep Kumar Rai. and Risam, K.S. 2012. Integrated Crop-Livestock Farming Systems: A Strategy for Resource Conservation and Environmental Sustainability. *Indian Research Journal of Extension Education*, Special Issue (Volume II), 49-54.

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- Hanumantha Rao, C.H. 1994. Some inter-relationships between agriculture, technology and livestock economy. In: Agriculture growth, rural poverty and environmental degradation in India. Oxford University Press, New Delhi, India, 155-194pp.
- NCAER. 2014. National council of applied economic research. An Analysis of Changing Food Consumption Pattern in India, National Council of Applied Economic Research, Parisila Bhawan, 11, I.P Estate, New Delhi, 22p.
- Ramana, D.B.V. 2008. Silvopastoral and hortipastoral models for small ruminant production. In: Alternate land use systems for resource conservation, emerging market needs and mitigation of climate change in rainfed regions, 16<sup>th</sup> January-5<sup>h</sup> February 2009, CRIDA, Hyderabad, 239-249pp.
- Ramana, D.B.V., Rai, P., Solanki, K.R and Singh, U.P. 2000. Comparative performance of lambs and kids under silvopastoral system. In: Proc. III Biennial ANA conference, Hissar.
- Ramana, D.B.V., Reddy, N.N and Rao, G.R. 2011. Hortipastoral systems for ram lamb production in rain fed areas. Annals of Biological Research, 2011, 2 (4) : 150-158.
- Sekhar, D.K., Tejeswara Rao, N. and Venugopala Rao. 2014). Studies on Integrated Farming Systems For Tribal Areas of Eastern Ghats In Andhra Pradesh. Indian Journal of Applied Research 4(10)14-15.
- Solaiappan, U., Subramanian, V. and Maruthi Sankar, G.R. 2007. Selection of suitable integrated farming system model for rainfed semi-arid vertic inceptisols in Tamil Nadu. Indian Journal of Agronomy 52 (3): 194-197.



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## Potential of Rain Water Harvesting Farm Ponds for Raising Farm Incomes in Rainfed Regions of Andhra Pradesh and Telangana

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The current emphasis of the development planning is on inclusive growth of the economy. There is an explicit target of doubling incomes of farmer households by 2022 (Chandra sekhar and Mehrotra, 2016). Both these objectives require a considerable increase in productivity and income from rainfed agriculture which is practised in nearly 60 per cent of net sown area. Rainfed agriculture is practised largely in arid and semi-arid environments wherein evapotranspiration exceed precipitation and also in dry sub humid regions to some extent. Rainfed agriculture is a significant contributor to production of coarse cereals, rice, pulses, oilseeds and cotton. Rainfed agriculture is characterized by poor natural resource base in terms of low and erratic rainfall, poor soils, shorter growing period and more importantly, the poor economic status of farmers (Venkateswarlu and Rama rao, 2011). As a result, the productivity levels in rainfed agriculture are considerably less than those achieved in irrigated agriculture and are also less than what can be achieved in rainfed environments (Rama rao *et al.*, 2010). By definition, rainfed agriculture is dependent on rainfall with little access to irrigation facilities. Rainfall in these regions is quantitatively inadequate in relation to evapo-transpiration demand, uncertain and unevenly distributed within a season resulting in long dry spells and drought like situations during crop growth period. Also, inter-annual variation is also observed in the seasonal rainfall. The productivity of rainfed crops can be significantly increased and protected if rain water can be harvested and used to irrigate crops (Rao *et al.*, 2010). In fact such an approach of harvesting rain water for using as a source of irrigation is recognized as an important part of strategy for betterment of rainfed agriculture.

Harvesting of rainwater through smaller structures called farm ponds constitutes an important component of watershed development programmes and is also largely supported through programmes such as MGNREGA. These farm ponds are generally dug out small scale water harvesting measure across the slope to capture run off water. Water so collected in these dug out structures is meant to protect a crop during a dry spell and also provide drinking water for livestock. Their life and utility can be enhanced if lined as recommended in red soil regions. When water is not used for irrigation, they can also help recharge groundwater. An analysis of the impact of adopting rainwater harvesting through farm ponds at the farm level in terms of changes in cropping pattern, cropping intensity and crop incomes in three districts is presented here.

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## Findings

The impact of farm ponds on the cropping pattern of the farm, yield of crops grown and area under cultivation for all the 100 ponds in each of the three districts and additional returns attributable to use of farm pond are presented in this section.

### Changes in cropping pattern

The Table 1 shows that changes in cropping pattern of the three study districts

#### *Anantapur district*

After farm ponds were dug, the farmers in Anantapur increased the area under sunflower (8ac), pearl millet (1.6 ha) and rice (0.6 ha), while there was decrease in the area of groundnut + pigeonpea. An additional area of 2.1 ha was brought under cultivation with farm ponds. The proportionate area sown to groundnut decreased by 4 per cent compared to 'before farm pond' situation.

#### *Chittoor district*

Area under cereal crops such as rice, pearl millet and maize increased after ponds came into being. With farm pond, area under tomato increased by 12.8 ha. Only rabi tomato showed a marginal decrease in area. There was significant decrease in the area of groundnut by 9.7 ha. After farm pond, some of farmers started growing crops like cotton, chilli, pearl millet and maize. These 100 farmers brought an additional 9.2 ha of land after having access to farm pond. This land was otherwise left as fallow before they had these ponds dug. In relative terms, area under tomato (kharif) increased by more than 10 per cent and that under groundnut decreased by about 15 per cent

#### *Adilabad district*

The area sown to cotton + pigeon pea, the major cropping system in the district, increased by about 16.2 ha for the 100 farmers as a whole. More area was also sown to tomato compared to before farm pond situation. Farmers started growing crops like green gram, rice, mango and sesame after digging farm pond, while sorghum, soybean and wheat showed a decline in area under cultivation. Through increase in irrigation through ponds the farmers could extend cultivation to an additional 16 ha.

**Table 1. Changes in cropping pattern after farm pond relative to before farm pond in three districts, 2012-13**

Chittoor			Adilabad			Anantapur		
Crop	Absolute change (ha)	Relative change (%)	Crop	Absolute change (ha)	Relative change (%)	Crop	Absolute change (ha)	Relative change (%)
Groundnut	-9.68	-15.3	Cotton+ pigeonpea	16.2	2.4	Groundnut +Pigeonpea	-3.3	-4.0
Tomato	12.76	10.7	Soybean	-4.2	-3.2	Sunflower	3.2	2.6
Rice	2.2	1.6	Tomato	2.6	0.8	Rice	0.6	0.4
Mango	0.8	0.6	Sorghum+ pigeonpea	-2.6	-1.9			
						Pearl millet	0	-0.1
Cotton	0.4	0.4	Green gram	-0.4	-0.3	Orange	0	0.0
Chilli	0.2	0.2	Dry rice	1.6	0.9	Pigeonpea	0	0.0
Tomato (rabi)	0.2	-0.1	Mango	2.4	1.4			
						Crossandra	0	0.0
Groundnut (rabi)	1.2	1.0	Sorghum (rabi)	-0.8	-0.6	Pearl millet (Rabi)	1.6	1.2
Pearl millet	0.8	0.7	Wheat	-0.4	-0.3	Rice (Rabi)	0	0
Maize	0.4	0.4	Tomato (rabi)	0.4	0.2			
			Groundnut (rabi)	0.4	0.2			
			Sesame	0.4	0.2			
			Chickpea	0.4	0.2			

*Note:* There was increase in total cropped area in all the districts. In Adilabad as much as an additional 16 ha was brought into cultivation because of the 100 ponds selected. The corresponding figures for Chittoor and Anantapur are 9.2 and 2.1, respectively.

### Impact of farm ponds on the yield of crops and income

Harvesting and use of rainwater led to considerable increase in the yield of crops grown (Fig 1). This together with changes in cropping pattern, area cultivated and cropping intensity resulted in increase in returns attributable to farm pond. The distribution of farm ponds based on the additional returns so generated are presented in figure 2.

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### ***Anantapur district***

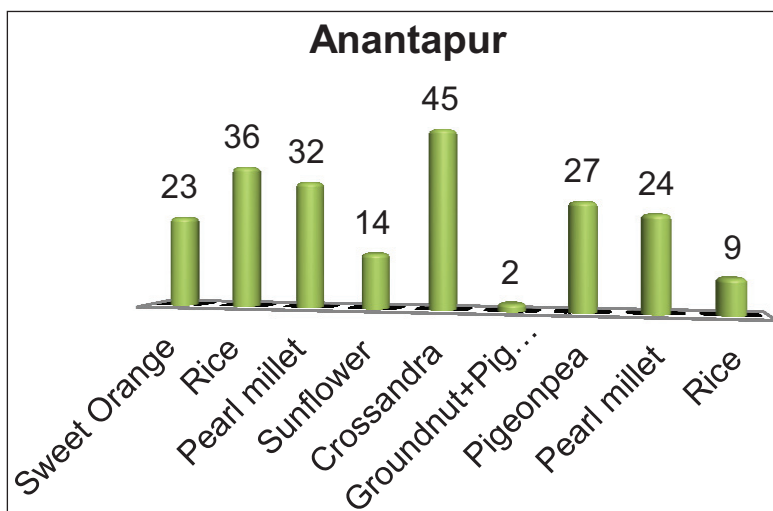
The yield increase after farm pond was highest for crossandra, rice and pearl millet. Groundnut, the major crop in the district, showed only a marginal yield gain. More than eighty percent of the farm ponds generated additional returns up to Rs.15000 per year. Sixty eight ponds could generate less than Rs.10000 and only ten ponds could generate an additional return of more than Rs 15000 per year. Of all the three districts, Anantapur received least annual rainfall presenting limited scope for harvesting water. However, it is also most crucial to protect the yields and incomes of farmers in such a situation.

### ***Chittoor district***

The yield of all crops increased by more than 25 per cent compared to a situation before farm ponds were dug. The yield gains were particularly visible in case of groundnut and tomato. Even the yield of mango, a perennial fruit tree, was also found to yield considerably higher probably because of groundwater recharge as it is not directly irrigated with harvested water. The highest yield increase was for mango followed by groundnut and tomato. The additional returns attributable to farm ponds varied widely. However, returns generated by 80 out of 100 ponds fell in the range of Rs.5000 -20000 per year. As mentioned, these additional returns arose due to changes in crop yields, cropping pattern, cropping intensity and additional area brought into cultivation.

### ***Adilabad district***

The district with relatively higher annual rainfall offers scope for bigger farm ponds as more runoff is possible. Though all the crops grown witnessed noticeable yield increases, higher yield gain was observed with green gram (80%) and tomato (45%). Crops like sorghum, groundnut and soybean also showed significant increases in the yield after farm pond. Majority of the farm ponds in this district generated returns more than Rs. 20000 per year.





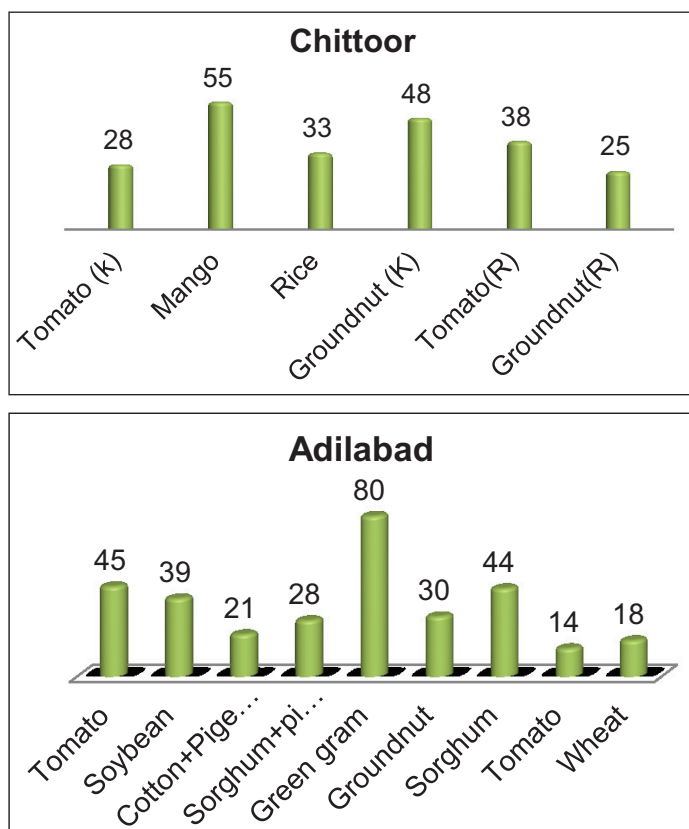


Fig. 1. Change (%) in the yield of crops after farm pond relative to before farm pond in the three districts, 2012-13

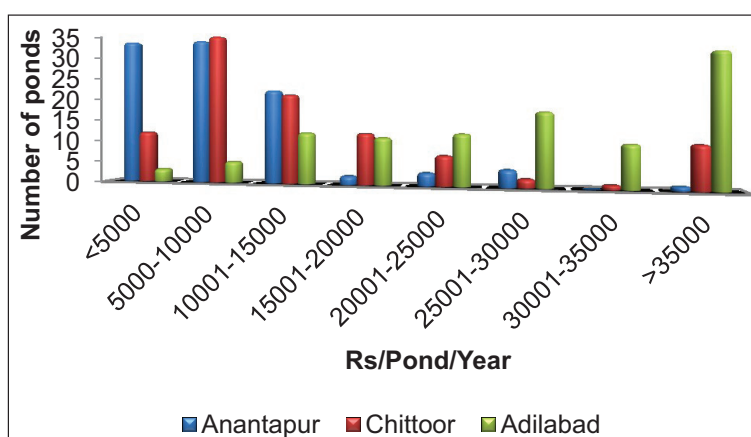


Fig. 2. Distribution of farm ponds according to additional returns generated in three districts, 2012-13

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In order to examine the financial feasibility of the farm ponds the benefit cost ratio and net present value were analysed for 100 ponds in each district. Assuming these returns would occur every year for a period of 15 years, the economic viability in terms of NPV (Fig 3) and BC ratio was calculated for all the 100 ponds each across the three districts. The BC ratio and NPV was found to vary significantly across the districts. The results of the same are discussed below.

#### ***Anantapur district***

It was observed that 33 out of 100 ponds gave an NPV of less than Rs.30000. It is interesting to note that four ponds recorded an NPV in excess of Rs. two lakhs and investment in 15 ponds was found to be unviable with a negative NPV. About 60 percent of the ponds had BC ratio less than 2.5 and with 15 ponds among them unviable. There were no ponds with BC ratio more than 15.

#### ***Chittoor district***

It is observed that 12 ponds out of 100 gave an NPV less than Rs.5000 out of which three ponds were found to be unviable with negative NPV. It is also interesting to note that three ponds recorded an NPV in excess of Rs. 5 lakhs (Fig 1). Majority of farm ponds (75 %) had BC ratio between 2.5 to 10 and eight ponds were more profitable with BC ratio more than 20.

#### ***Adilabad district***

The ponds in this district were found to be more profitable when compared to others. On an average the NPV of ponds was 2.5 lakhs while it was also found that investment in 3 ponds recorded NPV in excess of 6 lakhs. All 100 ponds were found to be viable. More than 60 percent of the ponds had BC ratio more than 10.

### **Determinants of profitability of farm ponds**

To examine the determinants of profitability of ponds, the additional returns generated per year was regressed on independent variables, viz., size of the plot where the pond is located (ac), size of the pond ( $M^3$ ), change in cropping intensity (%), whether water is lifted to irrigate the crop, whether there is a bore well in the plot and number of fillings in the season. The results for the three districts are presented in table 2.

#### ***Anatapur district***

The results indicated that four variables, size of plot, size of pond, change in cropping pattern and use of water for irrigation were found to have significant positive effect in increasing returns. Variables such as slope of the plot, presence of a bore well and number of fillings were not found to have significant effect. It was observed (Table 2) that the average size of the plot and pond were much higher in case of the most profitable ponds. Similarly, the yield effects were more prominent as well as the changes in cropping pattern.

The additional returns from farm pond was found to be associated with changes in cropping pattern in favour of horticultural crops such as sweet orange and tomato. The negative relationship between number of fillings and additional returns, though statistically not significant, in Anantapur and Adilabad districts was possibly due to moderation of benefits from farm pond in the years of better rainfall which lead to more frequent filling of ponds. The positive relationship in Chittoor can be attributed to the fact that the district receives rainfall with north-east monsoon as well and thus helps extend the cropping season and thus helps increase cropping intensity.

**Table 2. Determinants of profitability of farm ponds, Anantapur, Chittoor, and Adilabad**

Variable	Anantapur		Chittoor		Adilabad	
	Regression coefficient	Standard error	Regression coefficient	Standard error	Regression coefficient	Standard error
Constant	-3572.7	4798.6	-22305.30*	6611.48	12453.6	7236.35
Plot size	1661.5*	322.98	5064.72*	970.89	3310.71*	959.17
Pond size	39.49*	23.2	16.20	14.62	18.547*	5.98
Whether water is lifted	3874.34*	1544.06	4741.50	3451.32	15820.17*	5646.70
Change in cropping pattern	10456.89*	2147.91	8453.6*	2929.22	-276.341	2843.77
Change in cropping intensity	-1432.24	2516.31	4833.89	3517.26	-1776.94	5940.97
Whether bore well present in the same plot	-1783.83	1323.81	5781.95*	2922.77	-3416.69	4055.41
No. of fillings	-1162.58	837.163	5013.37*	1786.72	-409.87	1357.46
R <sup>2</sup>	0.55		0.44		0.34	

\* Significant at 5 per cent at least.

### ***Chittoor district***

It is observed from the table 2 that the profitability was significantly influence by the size of the plot where the pond was located. The number of fillings and cropping pattern change in favour of high value crops were also found to increase the profitability of farm ponds significantly. Additional crops like cotton, pearl millet, chilli and maize added to the existing cropping pattern increased profitability. Farm ponds also help in recharge of bore wells and thereby increasing the yields of crops.

### ***Adilabad district***

In this district, the size of the plot where the pond was located, size of pond and use of lifting device to pump water for irrigation were found to be positively influencing profitability of

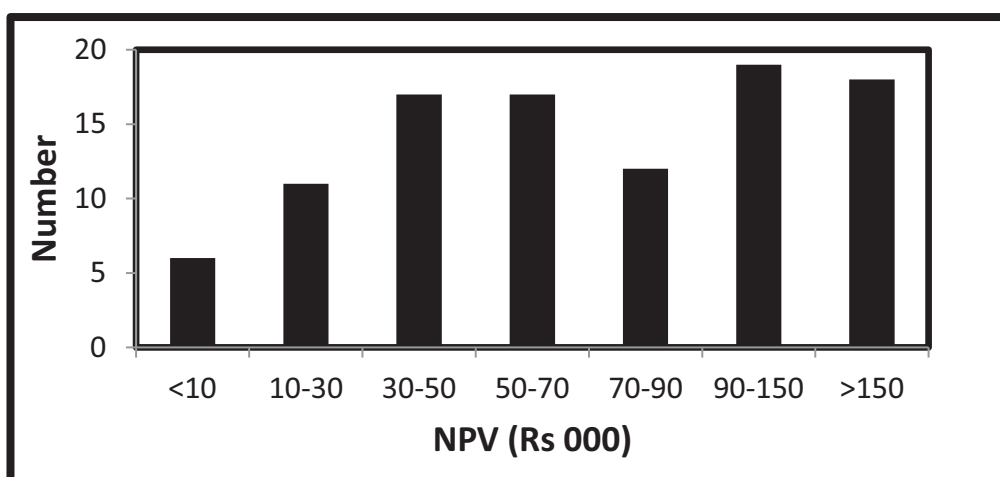
farm pond. Adilabad has comparatively bigger farm ponds making it possible to harvest more rainwater. These have also led to farmers to increase crop area with shifts in cropping pattern, thereby increasing the profitability of ponds (table 2).

### Performance differentiators of most and least profitable farm ponds

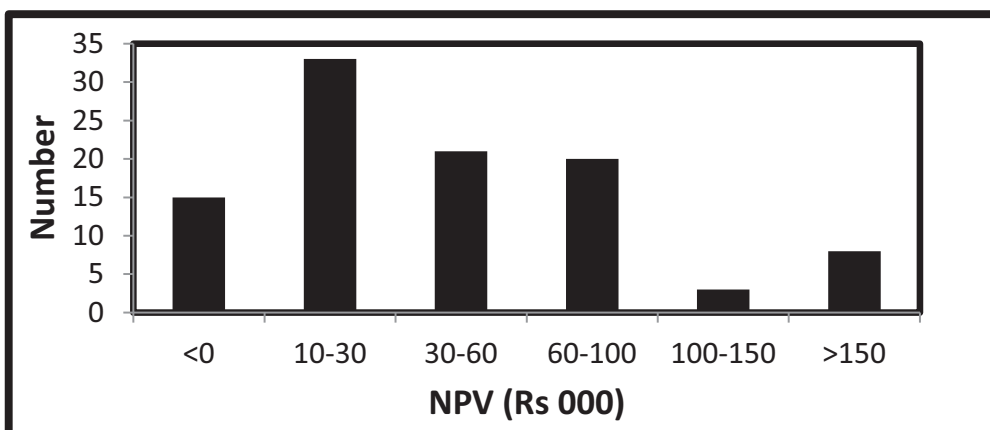
In order to further understand the determinants of profitability, the characteristics of five most profitable and five least profitable ponds were examined (Table 3). It was observed that the average size of the plot and pond were much higher in case of the most profitable ponds. Across the three districts, Adilabad had larger size ponds and plot size. The profitability of ponds also increased with increase in cropping intensity and changes in cropping pattern which is evident from the table. The top performing ponds also showed that they help in recharge of bore wells in the plot and also enough water is available for irrigation through pumping. While the least performing ponds either there no bore wells and pumping in Adilabad and Chittoor with exception of two in Anantapur district.

**Table 3. Characteristics of most and least profitable farm ponds in three districts**

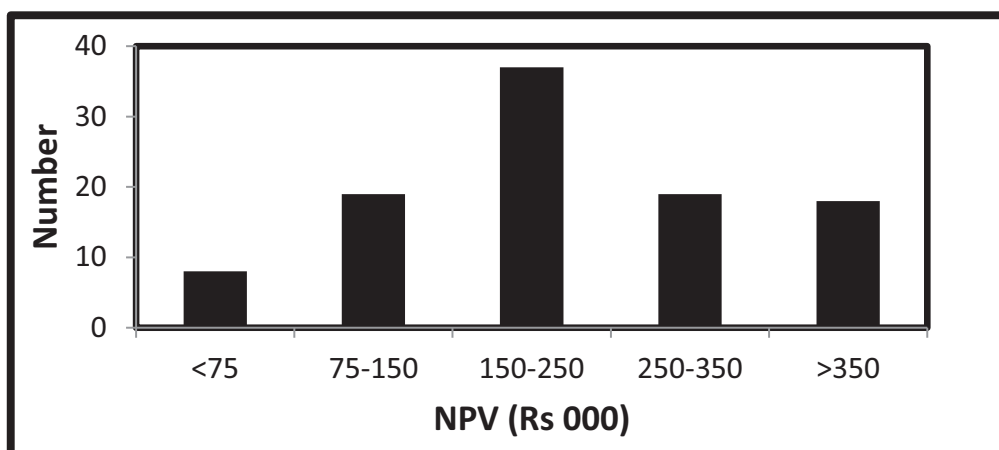
Variables	Chittoor		Adilabad		Anantapur	
	Top	Bottom	Top	Bottom	Top	Bottom
Cropping intensity (%)	131.43	100	114.4	112.9	179	100
Cropping pattern change (no.)	4	2	4	2	4	0
Bore wells (no.)	4	0	4	0	5	2
Pumping (no.)	1	0	4	0	3	1
Pond size (cu.m)	203	195	791.0	147.6	240	208
Plot size (acres)	3.2	1.1	5.5	3.2	5	2.3



(a)



(b)



(c)

**Fig. 3. Distribution of farm ponds based on net present value in (a) Anantapur (b) Chittoor and (c) Adilabad districts**

### Summary and policy implications

Improving the productivity of and income from rainfed agriculture should form an important element of any strategy for a more inclusive growth and doubling incomes of farmer households. In the context of rainfed agriculture, harvesting and use of rainwater for protective and/or productive irrigation assumes importance. This paper, using primary data from 300 farm ponds from three districts with varying rainfall, soil types and cropping pattern showed that rainwater harvesting through farm ponds was effective in enhancing farm incomes considerably across locations. The income gains were a result of improvement

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in crop yields, change in cropping pattern towards high value crops, increase in cropping intensity and expansion of cultivated area where the ponds were located. Further, the profitability returns due to farm pond were influenced by size of the plot where the pond was located, size of farm pond and when farmers were able to pump the water harvested to irrigate the crop through a pumping device. These findings imply that design of farm ponds should be location specific taking into consideration the rainfall and run off possibilities. Further, the plot where the pond is located should be reasonably large in size so that the harvested water can be gainfully utilized. If the pond and plot are too small, economic returns that can be generated may be too small to elicit interest of farmers. In Anantapur, most farm ponds located in plots less than 1 ha in size did not generate enough returns to meet the costs involved. That the incomes from plots where the ponds were located doubled in some cases underscores the potential role of farm ponds towards achieving the goal.

Interactions with farmers also brought out that during the years of normal/ above normal rainfall, the benefits from pond seem to be moderated. The farm ponds are also found to impact ground water recharge and access to irrigation. Though there is clear evidence of benefits from ponds still its adoption is less than what is possible. Unawareness and small farm size were major reasons for non-adoption. Therefore, the policy focus must be for the construction of water harvesting structures particularly farm ponds wherever feasible and public and private investment may be focussed to expand its adoption especially in rainfed regions of our country. Designing and making available low cost and more efficient pumping devices suitable to lift water from shallow depth may also help popularize farm ponds.

## References

- Chandra Sekhar, S. and Mehrotra, N. 2016. Doubling Farmers' Incomes by 2022: What would it take? *Economic and Political Weekly* 51 (18): 10-13.
- Rama Rao, C.A., Kareemulla, K., Nagasree, K., Venkateswarlu, B. and Shalander Kumar. 2011. Estimation of Economic Returns to Soil and Water Conservation Research – An ex ante Analysis, *Agricultural Economics Research Review* .Vol. 23 January-June 2010 pp 41-46.
- Rao, K.V. *et al.* (eds), In *Proceedings of National Workshop-cum-Brain Storming on Rainwater Harvesting and Reuse through Farm Ponds: Experiences, Issues and Strategies*, ICAR-CRIDA and ICRISAT, Hyderabad, 2010.
- Venkateswarlu, B., and Rama Rao, CA. 2011. Rainfed agriculture – Concerns, opportunities and strategies. *Yojana*, 55, 2011(Jan): p.37-40.

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## **Agromet Advisories and their Role in the Risk Management**

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Agriculture in India depends heavily on weather and climatic conditions. Weather forecasts are useful for taking decisions like choice of crop / crop variety, planting/harvesting dates, irrigation, fertilizer, pesticide, herbicide application etc. Hence, improved weather forecast based Agromet advisory services greatly help farmers to take advantage of beneficial weather and mitigate the impacts of malevolent weather conditions. Government of India established the National Centre for Medium Range Weather Forecasting (NCMRWF) under Department of Science & Technology (DST) in early 1988 in mission mode with the following mandate:

- Development of global and regional scale numerical weather prediction (NWP) models for forecasting weather in medium range (3-10 days) time scale taking full advantage of existing and concurrent developments both in India and abroad in the field of atmospheric science.
- Set-up a state-of-the-art supercomputing infrastructure to develop suitable NWP models to issue medium range weather forecasts.
- To inform and guide the farmers in advance to undertake various farming activities based on the expected weather.
- Set-up agro meteorological advisory service (AAS) units, each unit representing one of the 127 agro climatic zones spread all over India, to prepare/ issue/ disseminate AAS Bulletins based on weather forecasts and to provide user feedback as well.
- Set-up a stable/fast dedicated communication network with AAS units.

### **Agrometeorological advisory service at agro-climatic zone level**

One of the main objectives of NCMRWF was to give weather-based Agromet advisories to the farming community. The NCMRWF in collaboration with the India Meteorological Department (IMD), Indian Council of Agricultural Research (ICAR) and State Agricultural Universities (SAUs) had been operating Agro meteorological Advisory Service (AAS) at the scale of Agroclimatic Zone till March 2007. For this NCMRWF was using the numerical weather prediction based forecasting system operational at the centre. The country is divided into 127 agro-climatic zones with each zone covering about 4-6 districts. Agromet co-ordination cells have been working at ICAR and IMD to look after the requirements



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of project. SAUs have appointed Nodal Officers for its smooth implementation. Agromet Advisory Bulletins comprising of expert advice on crop, soils and weather are made available to the farming community. The AAS set-up exhibits a multi-institutional multidisciplinary synergy to render an operational service for the use of farming community.

The AAS units are located within SAU headquarters, their regional research stations and ICAR institutes. AAS Units had been receiving weather forecast from NCMRWF on bi-weekly basis (Tuesday and Friday). The forecast was issued for six parameters *viz.*, cloud amount (okta), precipitation (mm), wind speed (kmph), wind direction (degree), maximum temperature (°C) and minimum temperature (°C), in quantitative terms for next four days. In addition, the cumulative weekly precipitation (mm) was also provided.

The Nodal Officer in charge of the AAS Unit, generally an Agrometeorologist, in co-operation with an inter-disciplinary group of agricultural and extension specialists, such as, Plant Pathologists, Soil Scientists, Entomologists, Horticulturists, Agronomists etc., formulated the agro advisories. These advisories contained location specific and crop specific farm level advisories prepared in local language containing description of prevailing weather, soil & crop condition, and suggestions for taking appropriate measures to minimize the loss and also, optimize input in the form of irrigation, fertilizer or pesticides. Advisory content varied with location, season, weather, crop condition, and local management practices.

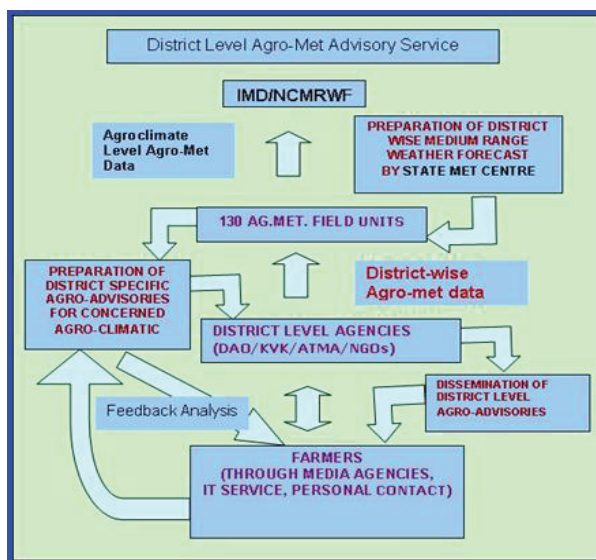
The entire framework of AAS, developed and successfully demonstrated by NCMRWF was later transferred to the India Meteorological Department (IMD) under MoES for extending the service (in operational mode) to the districts under these agro-climatic zones

### **Agrometeorological advisory service at district level**

Under Integrated Agro-Meteorological Advisory Service (IAAS), from 1<sup>st</sup> June, 2008 onwards, IMD has started issuing quantitative district level weather forecast up to 5 days. The products comprise of quantitative forecasts for seven weather parameters *viz.*, rainfall, maximum and minimum temperatures, wind speed and direction, relative humidity and cloudiness. In addition, weekly cumulative rainfall forecast is also provided. IMD, New Delhi generates these products using Multi Model Ensemble technique based on forecast products available from number of models in India and other countries. These include: T-254 model of NCMRWF, T-799 model of European Centre for Medium Range Weather Forecasting (ECMWF); United Kingdom Met Office (UKMO), National Centre for Environmental Prediction (NCEP), USA and Japan Meteorological Agency (JMA). The products are disseminated to Regional Meteorological Centres and Meteorological Centres of IMD located in different states. These Meteorological Centres undertake value addition to these products using synoptic interpretation of model output and communicate to 130 Agromet Field Units (AMFUs), located in different State Agriculture Universities (SAUs), institutes of Indian Council of Agriculture Research (ICAR) etc. on every Tuesday and Thursday (Fig. 1). These networks of 130 AMFUs covering all agro-climatic zones of the country are under the Ministry of Earth Sciences (MoES), Government of India. They are

operated at State Agriculture Universities (SAUs), Indian Council of Agricultural Research Institutions (ICAR) and Indian Institute of Technology (IIT). These units are responsible for recording agro meteorological observations, preparing medium range weather forecast based Agromet advisories for the districts falling under concerned Agroclimatic zones and dissemination of the same.

### Agromet Advisory Services (AAS) at micro (block) level

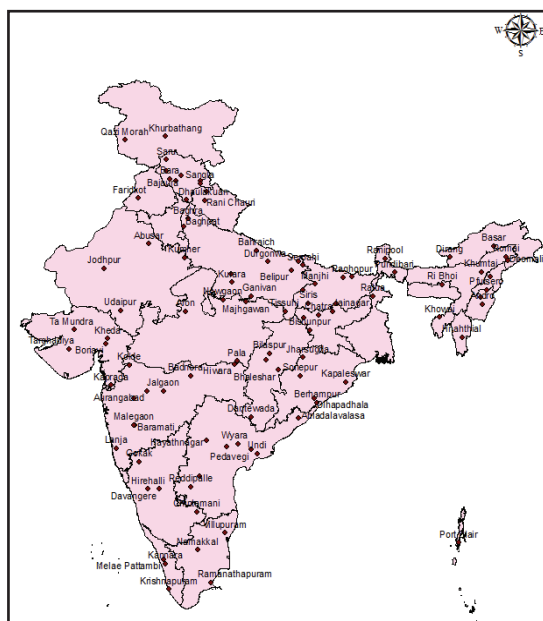


**Fig. 1. District level Agro-met Advisory Service**

So far issue of Agromet advisory services by IMD or NARS centres is limited to district level only. District is too big a unit and district level advisories may not be accurately addressing the problems at block or taluka level. Hence, All India Coordinated Research Project on Agrometeorology under the flagship Project “National Initiative for Climate Resilience in Agriculture (NICRA)” initiated efforts to improve the existing Agromet Advisory Services and to extend them to block level from the district level. As current weather conditions along with weather forecasts and crop conditions is a pre-requisite for preparing Agro Advisory services, efforts were made to monitor daily weather conditions at a number of network stations, the details areas under:

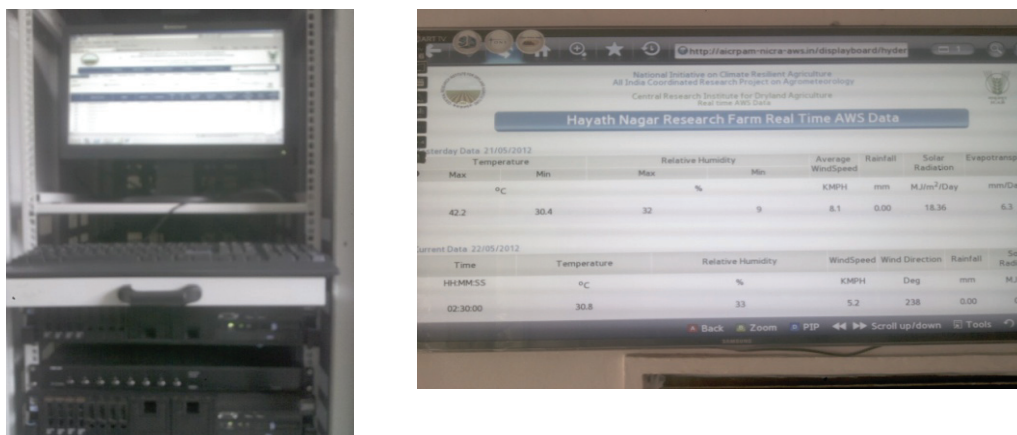
### Establishment of Automatic Weather Station (AWS) Network

Across the country, 100 KVKs were selected according to the climatic vulnerability for the installation of Automatic Weather Stations (AWS) to provide the weather based agro advisories (Fig.2). The major components of AWSs are (1) Sensors for measuring various atmospheric Parameters, (2) Data Logger for interface between sensors, communication system and power supply and storage of data, (3) Communication System for transmitting data to a remote location, (4) Power Supply, and (5) Mounting Platform.



**Fig. 2. Location points of 100 Automatic Weather Stations installed**

As on 13<sup>th</sup> March 2012, the installation of all the Automatic Weather Stations was completed at 100 locations. The AWS at the locations are measuring meteorological parameters, viz., Maximum & Minimum Temperature, Maximum & Minimum Humidity, Wind speed & Direction, Rainfall, Solar Radiation and Potential evapotranspiration at 30 minute interval. The AWS uses GSM-GPRS/SMS Communication Unit for Wireless Data Transfer. The data from the AWS is flowing continuously to the Central Server facility established at Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad (Fig. 3).



**Fig. 3. NICRA-AWS Server at AICRPAM-CRIDA and display pattern**

A web site is designed and developed to retrieve the data from all the 100 AWS and after finishing the quality check it is made accessible at NICRA AWS website <http://www.aicrpam-nicra-aws.in> (Fig. 4).



Fig. 4. NICRA-AWS Website

### Micro-level agromet advisory services (AAS)

Even though age old experience and knowledge inherited by the farmers, the increasing frequency of rapid change in weather/climate, generating uncertainty. Many of the farmers depend on indigenous knowledge for predicting weather and plan their crops and their management. The advent of forecasting technologies and decision making skills have not yet spread among small and marginal farmers who are major chunk of farming community in the country. In general, weather information helps the farmers in cultivars selection, choosing windows for sowing/harvesting operations, irrigation scheduling and optimal water use, mitigation from adverse weather events such as frost, low temperature, heavy rainfall at critical crop stages, nutrient management through fertilizer application, plant protection measures such as pesticide/fungicide spraying schedules, feed, health and shelter management for livestock.

At this juncture, Indian Council of Agricultural Research (ICAR) under National Innovations in Climate Resilient Agriculture (NICRA) project has taken major initiative to address the above mentioned issues of weather and climate on Indian agriculture and also

to realize the present day needs of the farmers of the country. This paper deals with how agro-met advisories at district level are issued and further the planning and implementation of microlevel agro-met advisories at block level, which helps the farmer to improve the crop protection from different weather aberrations and sustain the production with more benefits. Agromet advisory service envisaged to be implemented from the year 2012-13 was meant for creating awareness among farmers about weather and climate and its importance in agriculture. This information can be used in crop management like in day to day field operations and it will enhance farmer's capability towards climate resilient agriculture. The farmers receive the forecast prepared by Scientist (Agrometeorologist) or SRF of the KVK and the advisory is disseminated directly in person. The farmers receive the Agromet advisories for their own taluka / blocks. Agromet advisory is based on ground level information. The Officers of State Department of Agriculture and NGOs also receive our advisories for their respective talukas/ blocks through email. This helps them to disseminate the advisories to their contact farmers without losing any time.

### Block Level agromet advisory service in Belgaum District- A Pre-pilot project in operation

Under NICRA project the district level weather forecast is being used along with current crop and weather condition for preparation of block level advisories by respective KVK. A pilot methodology for preparing and issuing Agromet advisories has been devised at KVK, Belgaum (Fig. 5). Field Information Facilitators (FIF) have been appointed in 10 Talukas of the district to collect information on weather, crops, disease and pest incidence.

#### *Development and dissemination of Agromet Advisories*

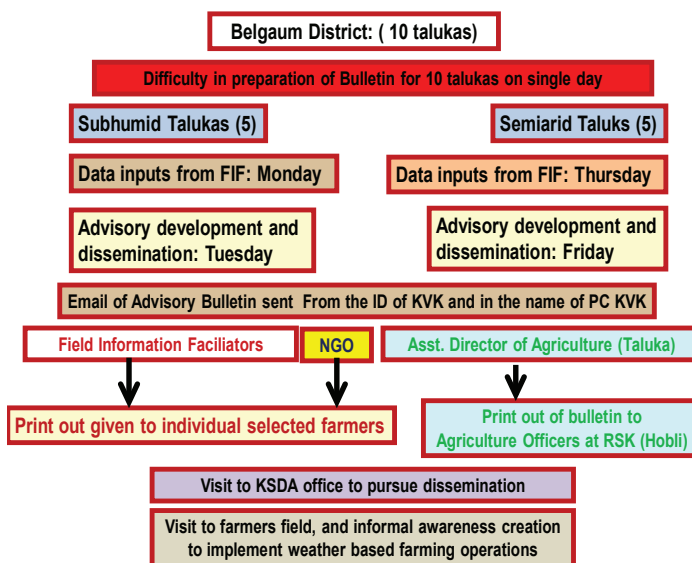


Fig. 5. Methodology for dissemination of AAS

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The FIFs also collect qualitative information on soil moisture stress and animal husbandry. They supply information telephonically or by e-mail to SRFs who in turn develop a qualitative Agromet Advisory specific to the village/farmers, in consultation with Agrometeorologist and Scientists of KVK. This helps in further value addition in terms of management options. Each FIF is covering 200 farmers in each Taluka and FIFs then disseminate the Agromet advisory through distribution of handouts individually to selected farmers and by visiting farmers fields and holding informal awareness programs. This facilitates the farmer to utilize the forecast with maximum lead time.

### **Way forward**

- Develop KVKs, which are located in more than 600 districts of the country, as hubs for formulation and dissemination of Agromet advisories at district / block level.
- Value addition to Agromet information for improving the efficiency of agromet advisories and its dissemination in local languages using latest ICTs.
- Studies on dynamics of pests and disease in a cropping system mode as well as development of thumb rules for weather based forewarning models and Decision Support Systems (farmer-friendly and economically viable).
- New thrust areas on Agrometeorological aspects in horticulture, livestock and agriculture in hill and island regions.
- Application of Remote Sensing in AAS through linking Remote Sensing (RS) products with crop growth simulation model and decision support tools.
- Develop interactive Agrometeorological information system that delivers a family of user-selectable products to meet customer needs via Internet and mobile phones.
- There is a need for IMD to make improvement in monitoring and prediction of disastrous weather like heavy rain/snowfall over data sparse Himalayan region and adjoining plains and cyclonic disturbances over north Indian Ocean using land/ Ocean and space based tools.
- There is a need for IMD to make improvement in nowcast of meso-scale disastrous events like thunderstorm, hailstorm and tornado.





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## **Increasing Atmospheric CO<sub>2</sub> Concentration and Temperature - Impact on Rainfed Crops Productivity**

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The changes in the composition of atmosphere in terms of greenhouse gases, aerosols influence the properties of solar radiation and alter the energy balance of the climate system. Now it is evident from various studies that the human activities are contributing significantly for the change in climate compared to natural variability in climate. General circulation models predict temperature rises of 1.4-5.8°C by 2100, associated with carbon dioxide increases to 540-970 parts per million. The atmospheric concentration of carbon dioxide- the most important anthropogenic greenhouse gas increasing at alarming rates (2.1 ppm per year) in recent years than the natural range concentration growth rate. This could be due to enhanced usage of fossil fuel and changed land use pattern to some extent. Climate change due to increasing concentrations of green house gases in the atmosphere since the pre-industrial times has emerged as a serious global environmental issue and poses a threat and challenge to mankind. The Fourth Assessment report of Intergovernmental Panel on Climate Change (2007) concluded that ‘there is high confidence that recent regional changes in temperature have had discernible impacts on many physical and biological systems’. Climate model predictions of CO<sub>2</sub> induced global warming typically suggest that rising temperatures should be accompanied by increases in rainfall amounts and intensities, as well as enhanced variability. The climate sensitivity of agriculture is uncertain, as there is regional variation of rainfall, temperature, crops and cropping system, soils and management practices. The inter-annual variations in temperature and precipitation were much higher than the predicted changes in temperature and precipitation. The crop losses may increase if the predicted climate change increases the climate variability. Different crops respond differently as the global warming will have a complex impact.

Both the number and intensity of heavy precipitation events are projected to increase in a warming world, according to the IPCC. The mean atmospheric temperatures of the globe have been on the increase and the number of years recorded the highest temperatures are increasing and the year 2016 surface temperatures were the warmest since modern record keeping began in 1880 as reported by NASA and NOAA. Many regions across the world started witnessing increased occurrence of extreme weather events. There have been events of increased number of intense cyclonic events and increase in occurrence of high rainfall events, even though the quantum of rainfall had not shown large changes. The frequency of occurrence of heat and cold waves is on the increase. Significant changes in daily maximum

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and minimum temperatures are observed. Of the 882 million hectares of cropland worldwide in 2015, only 314 million hectare is irrigated and the remaining is rainfed. The importance of rainfed agriculture varies regionally, and is most significant in country like India where rainfed agriculture accounts for about 65% of the cropland and 70% of population main occupation. Under current water use practices, increases in population and changes in diet are projected to increase water consumption in food and fiber production by 70-90%. If demands for biomass energy increase, this may aggravate the problem. In addition, sectoral competition for water resources will intensify, further exacerbating the stress on developing country producers. Throughout the 20th century, global water use has increased in the agricultural, domestic and industrial sectors. Evaporation from reservoirs has increased at a slower rate. Projections indicate that both global water use and evaporation will continue to increase.

Rice, wheat, maize, sorghum, soybean and barley are the six major crops in the world and they are grown in 40% cropped area, 55% of non-meat calories and over 70% of animal feed (FAO, 2006). Since 1961, there is substantial increase in the yield of all the crops. The impact of warming was likely offset to some extent by fertilization effects of increased CO<sub>2</sub> levels. At the global scale, the historical temperature- yield relationships indicate that warming from 1981 to 2002 very likely offset some of the yield gains from technological advance, rising CO<sub>2</sub> and other non-climatic factors. The carbon dioxide level in the atmosphere has been rising and that this rise is due primarily to the burning of fossil fuels and to deforestation. Measured in terms of volume, there were about 280 parts of CO<sub>2</sub> in every million parts of air at the beginning of the Industrial Revolution, and there is 407 ppm today, a 30 percent rise. The annual increase is 1.9 ppm, and if present trends continue, the concentration of CO<sub>2</sub> in the atmosphere will double to about 700 ppm in the latter half of the 21<sup>st</sup> century. Carbon dioxide is the basic raw material that plants use in photosynthesis to convert solar energy into food, fiber, and other forms of biomass. In the presence of chlorophyll, plants use sunlight to convert carbon dioxide and water into carbohydrates that, directly or indirectly, supply almost all animal and human needs for food; oxygen and some water are released as by-products of this process. Voluminous scientific evidence shows that if CO<sub>2</sub> were to rise above its current ambient level, most plants would grow faster and larger because of more efficient photosynthesis and a reduction in water loss. There are two important reasons for this productivity boost at higher CO<sub>2</sub> levels. One is superior efficiency of photosynthesis. The other is a sharp reduction in water loss per unit of leaf area. By partially closing the stomata, higher CO<sub>2</sub> levels greatly reduce the plants' water loss- a significant benefit in arid and semi arid climates where water is limiting the productivity.

There are marked variations in response to CO<sub>2</sub> among plant species. Most green plants, including most major food crops use the C3 pathway respond most dramatically to higher levels of CO<sub>2</sub>. At current atmospheric levels of CO<sub>2</sub>, up to half of the photosynthates in C3 plants is typically lost and returned to the air by a process called photo-respiration;

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Elevated levels of atmospheric CO<sub>2</sub> virtually eliminate photo-respiration in C3 plants, making photosynthesis much more efficient. Corn, sugarcane, sorghum, millet, and some tropical grasses use the C4 pathway, also experience a boost in photosynthetic efficiency in response to higher carbon dioxide levels, but because there is little photo-respiration in C4 plants, the improvement is smaller than in C3 plants. Instead, the largest benefit C4 plants receive from higher CO<sub>2</sub> levels comes from reduced water loss. Loss of water through leaf pores declines by about 33 percent in C4 plants with a doubling of the CO<sub>2</sub> concentration from its current atmospheric level. Since these crops are frequently grown under drought conditions of high temperatures and limited soil moisture, this superior efficiency in water use may improve yields when rainfall is even lower than normal. When there was no stress, elevated CO<sub>2</sub> reduced stomatal conductance by 21.3 and 16.0% for C<sub>3</sub> and C<sub>4</sub> species respectively. The lowest response to higher CO<sub>2</sub> levels is usually from the CAM plants, which include pineapples, agaves, and many cacti and other succulents. CAM plants are also already well adapted for efficient water use.

The mean response to doubling of the CO<sub>2</sub> concentration from its current level is about 32 to 35% improvement in plant productivity, with varied manifestations in different species. In crop plants, a distinction has to be made between the increase in total biomass and increase in economic yield resulting from an elevated CO<sub>2</sub> supply. When the dry mass production and yield increase of the world's ten most important crop species in response to elevated CO<sub>2</sub> was analyzed from different experiments, it was found that in some species the relative increase of total biomass and in others that of economic yield is greater. Cereal grains with C3 metabolism, including rice, wheat, barley, oats, and rye, show yield increases ranging from 25 to 64%, resulting from a rise in carbon fixation and reduction in photo-respiration. Food crops with C4 metabolism, including corn, sorghum, millet, and sugarcane, show yield increases ranging from 10 to 55%, resulting primarily from superior efficiency in water use. Tuber and root crops, including potatoes and sweet potatoes, show dramatic increase in tuberization (potatoes) and growth of roots (sweet potatoes). Yield increases range from 18 to 75%. Legumes, including peas, beans, and soybeans, show yield increases of 28 to 46%.

Field crops under drought often experience two quite different but related and simultaneous stresses: soil water deficit and high temperature stresses. Elevated CO<sub>2</sub> increase growth, grain yield and canopy photosynthesis while reducing evapotranspiration. During drought stress cycles, this water savings under elevated CO<sub>2</sub> allow photosynthesis to continue for few more days compared with the ambient CO<sub>2</sub> so that increase drought avoidance. Elevated atmospheric CO<sub>2</sub> concentration ameliorates, to various degrees, the negative impacts of soil water deficit and high temperature stresses.

Both the mean and extreme temperatures that crops experience during the growing season will change in both temperate and tropical areas. Extreme temperatures are important because many crops have critical thresholds both above and below which crops are

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damaged. Majority of the crops tend to respond negatively, when the temperature exceeds optimum range and leads to reduced yield. However, the optimum temperature of different crops and their vulnerability to high temperatures varies with the genotype, developmental stage and duration of exposure. High temperature during the reproductive stages causes deleterious effects on the yield and quality. Exceeding crop-specific high temperature thresholds may result in a significantly higher risk of crop failure.

As vegetative and reproductive process have different responses to temperature therefore show different stimulations by CO<sub>2</sub> at elevated temperature, hence beneficial effects of elevated CO<sub>2</sub> on photosynthesis, carbohydrate metabolism and vegetative growth are not always reflect in seed yield. The biomass and yield response of sunflower hybrid KBSH-1 to elevated CO<sub>2</sub> of 550ppm differed with two temperature regimes. When the crop experienced maximum temperature of below 35°C during the anthesis and grain filling stages, the elevated CO<sub>2</sub> (550ppm) improved total biomass by 19% and seed yield by 21% and when it was exposed to more than 40°C the response was reduced for the biomass (2%) and seed yield (9%). The FATE studies with groundnut cv. Dharani at elevated canopy temperature (eT) recorded reduction in total biomass (20.4%), pod number (9.4%), seed yield (34.3%), while the presence of elevated CO<sub>2</sub> (550ppm) at high temperature reduced the ill effects of high temperature showing the protective effect of elevated CO<sub>2</sub> against high temperature.

Agriculture is sensitive to climate change at the same time it is one of the major driver for climate change. The impact of the future predicted increased CO<sub>2</sub> and temperature coupled with changes in precipitation patterns for majority of rainfed crops appears to be not that distressing. However to counter the adverse effects of climate change on agriculture, it is desirable to select the crops and their cultivars thereof, that can better utilize the increased concentration of CO<sub>2</sub> and perform better under high temperature and moderate moisture deficit conditions. Understanding the weather variables over a period of time and setting the management practices for better harvest is required for the growth of agricultural sector as a whole.

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## **Extension Tools and Techniques for Technology Dissemination in Dryland Agriculture**

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The dryland agriculture plays an important role in the progress of agriculture in the Indian economy. The most important contributing character in the drylands is low rainfall, within a range of from 375 to 1125 mm which are unevenly distributed, highly erratic and uncertain. The crop production in drylands is mainly dependent on the frequency and intensity of rainfall making it a less productive. In India 68 per cent of total net sown area (136.8 m ha) comes under dry lands spread over 177 districts. Dry land crops account for 48 per cent area under food crops and 68 per cent area under non-food crops. Nearly 50 per cent of the total rural work force and 60 per cent of livestock in the country are concentrated in the dry districts (DHAN Foundation, 2006). Rainfed agriculture is practiced in two-thirds of the total cropped area of 162 million hectares (66 per cent).

Green revolution was concentrated on the irrigated pockets of India leading to the neglect of the rainfed regions, but the continuation of such neglect can have serious consequences. The boon of green revolution led to disparity in terms of income and prosperity among the different regions of the country. In India, Fan and Hazel (2000) have estimated that 82% of the rural poor live in rainfed areas. Such people are highly vulnerable to climatic fluctuations. If the rains fail, the consequences are crop failure and reduction of feed availability for grazing animals. It is high time that proper attention is given to the farmers in rainfed regions towards doubling their income. The rainfed lands suffer from a number of bio-physical and socio-economic constraints which affect productivity of crops and livestock. These include low and erratic rainfall, land degradation and poor productivity (Abrol and Katyal, 1994), low level of input use and technology adoption, low draft power availability (Mayande and Katyal, 1996), inadequate fodder availability low productive livestock (Singh, 1997), and resource poor farmers and inadequate credit availability. Research investments addressing the problems of dryland agriculture is proportionately smaller leading to lower productivity and persistence of poverty. As a result there is a lower performance of the research system in replacing existing technologies by new ones in rainfed than in irrigated areas. This may be partly because of the failure on the part of the researchers in targeting farmers' needs precisely and also due to the lower research intensity in the rainfed areas. While extension needs expertise and interactions of a problem solving nature, what research often provides is broad or generic technical recommendations. There is huge variation in the natural resource base, farming systems and socio-economic conditions of farmers in rainfed regions and broad technological recommendations make vary little sense in these kinds of situations (Sulaiman, 2012).

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## **Role of Agricultural extension in Dryland agriculture**

Agricultural extension has an important role to play in Dryland agriculture. The complex nature of Dryland farming requires careful planning and execution of extension programmes. In order to achieve stability in Dryland production, an integration of long, medium and short term technologies are needed. The technologies developed must be in a watershed basis with people's participation. Farmers in Dryland areas are resource poor, small and marginal farmers. Technologies developed for this region should be location and resource specific. Methodologies should be developed to initiate and encourage farmers' participation in dryland agriculture. Participatory rural appraisal, group interaction of farmers to know more about farmer perception are to be utilized for the better understanding of a programme to make it beneficial for the dryland farmers (Rao and Ryan, 2004 and Singh *et al.*, 2004). Grass root level extension is to be the prime criteria. Even though there is tremendous growth in agricultural research and education, a vast number of farmers are not been exposed to the improved technologies which are been developed. This results in reduction in the final output of the whole improvement of the drylands. Nongovernmental organization having linkages with farmers has been working well in many parts of Indian drylands. The self-help group approach is also gaining momentum in many states of India. All the approaches put together will help to develop the land for a sustainable production (Rao and Ryan, 2004 and Singh *et al.*, 2004). The indigenous technical knowledge (ITKs) which are present in the farming communities on the various aspects of farming could be refined with the modern research facilities. The refined ITKs are more readily accepted by the farmers (Rao and Ryan, 2004 and Singh *et al.*, 2004). Other technical knowledge of remote sensing can also be utilized in mapping the drylands based on various criteria and further utilization into development of area based projects. Extension professionals in dryland areas choose appropriate technologies for the upliftment of the farmers.

## **Extension Tools and Techniques for Technology Dissemination in Dryland Agriculture**

The generation and application of agricultural knowledge is increasingly important, especially for small and marginal farmers, who need relevant information in order to improve, sustain and diversify their farm enterprises. Most of the time the farmers are not much aware of the latest technologies developed for the improvement of agricultural products. It is a fact that there are different methods of extension system of information and technology but to reach rural people is always a difficult task because of remoteness of the places and the level of consciousness. Development and progress cannot take place unless those who participate in the process are socially, economically, technologically and politically literate (Layle D. Lawrence, 1998). Technology transfer in agriculture should focus on key interventions at different stages of the crop from sowing of the seed, crop protection and harvesting, post-harvest management to marketing. Technology transfer needs effective interactive groups like Self Help Groups and Farmers Clubs which should become tools of disseminating information about various government sponsored schemes and these entities will help in liaising with various government departments for developmental activities.



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Internet and mobile phones are potential tools to Impart knowledge on new developments, improved methods of cultivation/ technologies in the field of agriculture. These tools can also be useful in dissemination of weather data and agro climatic conditions, latest information on prices of agriculture produce to farmers. Village Knowledge Centres and online databases in local languages will help in fast technology dissemination which will certainly reduce the knowledge deficit with the farmers and will help in accelerating the stagnant growth of agriculture, realizing higher potential of our land and hard work of our farmers. In general there are three types of extension methods for technology dissemination. They are (a) individual method, in which the agent deals with farmers on a one-to-one basis; (b) group method, in which the agent brings the farmers together in one form or another in order to undertake his extension work; and (c) mass contact method, which can expose large numbers of people to the same information at the same time. Each of these methods demands different approaches and techniques on the part of the agent. All these methods are suited to different purposes and the selection is done appropriate to the situation. It is also important to consider the educational purpose of extension work, and to ensure that the method selected is used to promote the farmers' better understanding of the technology involved.

### **Individual methods of extension**

Individual or face-to-face methods are probably the most universally used extension methods in both developed and developing countries. The extension agent meets the farmer at home or on the farm and giving the farmer both information and advice. Learning is very much an individual process and the personal influence of the extension worker can be a critical factor in helping a farmer through difficult decisions, and can also be instrumental in getting the farmer to participate in extension activities. This individual contact between the extension agent and the farmer can take a number of forms as follows:

***Farm visits:*** Farm visits are the most common form of personal contact between the agent and the farmer and often constitute over 50 percent of the agent's extension activities.

***Office calls:*** The farmer will visit the extension agent at his office.

***Letters:*** The extension agent will correspond with a farmer by letter. Letters can be a follow-up inquiry resulting from an agent's farm visit, or sent because a farmer is unable to make a personal office visit.

***Telephone calls:*** Telephone calls help the extension worker to deal with many of the farmers in his area (if at all) by telephone. This method is used for passing on specific advice or information.

***Informal contacts:*** Informal contacts will occur continually during the agent's stay in a particular area. Market days, holiday celebrations or religious events will bring him/her into contact with the farmers with whom he/she is working who will inevitably talk about their problems. By attending such events, the agent can become well acquainted with the



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area where he/she works and with the farmers and their problems, and he/she will be able to pass on ideas and information on an informal basis.

### **Group methods of extension**

The use of groups in extension has become more common over the past decade, and a number of new ideas have emerged about how groups may be used most effectively. For example, the widespread Small Farmer Development Programme (SFDP) in Southeast Asia was based upon group methods and it has produced two manuals which detail the approach of group extension work. Furthermore, in Latin America, work with extension groups in Brazil and Colombia has shown the usefulness to extension of the formation of extension groups and how these groups can support extension activity. To form structure and develop a group of farmers for extension purposes is a complex process, and such groups do not appear overnight. There are four sets of important issues that the agent will have to bear in mind to bring the farmers together for a particular activity, which includes purpose, size, membership and extension agent's relationship with group.

**Group meetings:** The group or community meeting is a useful educational forum where the agent and farmers can come together, and ideas can be openly discussed and analysed. Depending on the purposes group meeting can be Information meetings (The agent calls the group or community together to communicate a specific piece of new information which he/she feels will benefit them and upon which he/she seeks their advice), Planning meetings (To review a particular problem, suggest a number of solutions and decide upon a course of action), Special interest meetings (Topics of specific interest to a particular group of people like horticulture, bee keeping, or dairy farming are presented and discussed in detail), General community meetings (Men, women and young people of a community are invited to attend and discuss issues of general community interest).

**Demonstrations:** The demonstration is a powerful method to use with farmers who are illiterate. It will give such farmers the opportunity to observe, at first hand, the differences between a recommended new crop practice and traditional practices. There are two principal types of demonstration used by extension agents - method demonstration and result demonstration. Method demonstrations basically show farmers how to do something. In this, the farmer is shown step by step how, for example, to plant seeds in line, to use a mechanical duster to control insects. The agent will probably be dealing with farmers who have already accepted the particular practice being demonstrated, but who now want to know how to do it themselves. The main advantage of the method demonstration is that the extension agent can explain simple farming skills to a large number of people. The main purpose of a result demonstration is to show local farmers that a particular new recommendation is practicable under local conditions. Comparison is the important element in a result demonstration: comparison between compost and no compost or between poor seed and selected seed. "Seeing is believing" is an age-old expression, but one appropriate to a result demonstration. By showing tangible results of a new practice recommended by the extension service, the agent can help to create confidence among the farmers and can greatly encourage them to try the practice themselves.

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**Field days:** Field days are usually opportunities to hold method or result demonstrations on a slightly larger scale, and are usually run in a more informal and less highly structured manner. The purpose is often to introduce a new idea and a new crop, and to stimulate the interest of as many farmers as possible. Experimental stations or other government centres may be used for field days. There is a greater chance of making an impact if the field day is held on a farmer's land, and if the farmer plays a part in running it and explaining the purpose.

**Tours:** The tour should give local farmers a chance to see how other farmers cultivate their land, and to exchange ideas and experiences with them. It is important, therefore, that the area to be visited be in some way similar agriculturally to that of the visiting farmers.

### **Mass media in extension**

Mass media are those channels of communication which can expose large numbers of people to the same information at the same time. The attraction of mass media to extension services is the high speed and low cost with which information can be communicated to people over a wide area.

**Radio:** Information can reach households directly and instantly throughout a region or country with the help of radio. Urgent news or warnings can be communicated far more quickly than through posters, extension agents or newspapers.

**Audio cassettes:** Audio cassettes found to be a useful extension tool, particularly where information is too specific to one area for it to be broadcast by radio.

**Film:** The main advantage of film is that the audience can see as well as hear the information it contains. It is easier to hold an audience's attention when they have something to look at. It also makes it possible to explain things that are difficult to describe in words, for example, the colour and shape of an insect pest or the correct way to transplant seedlings. Scenes from different places and times can be brought together in order to teach processes that cannot normally be seen directly. The causes of erosion, for example, can be demonstrated dramatically by showing how a hilltop stripped of trees no longer prevents rain-water running down the slope, creating gullies and removing topsoil.

**Television and video:** Television, like film, combines vision with sound and like radio; it can also be an instant medium, transmitting information directly to a mass audience. Video combines most of the advantages of film and of audio cassettes. This enables the production team to re-record any material that is not satisfactory. As with audio cassettes, unwanted information can be removed and the tape reused.

**Print media:** Printed media can combine words, pictures and diagrams to convey accurate and clear information. Their great advantage is that they can be looked at for as long as the viewer wishes, and can be referred to again and again. Printed media used in extension include posters, leaflets, circular letters, newspapers and magazines.

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**Exhibits and displays:** Apart from being a useful way of sharing information, an attractive, neat display suggests to people that the extension agent and his organization are efficient and keen to communicate. Displays are suitable for notice boards inside and outside extension offices, at demonstration plots (where the progress of the demonstration can be recorded in pictures), and at agricultural shows.

**Campaigns:** In an extension campaign, several media are used in a coordinated way and over a limited period of time in order to achieve a particular extension objective.

**Traditional media:** Traditional forms like songs, dances and plays can convey information in an interesting way. Even when they are prepared in advance, they can be adapted at the last minute to cater to local situations and response from the audience. No modern technology is required and these media are especially useful where literacy levels are low. By involving local people in preparing the plot of a play, extension agents can stimulate the process of problem analysis, which is a fundamental part of the educational aspect of extension.

### **Innovations in Technology dissemination**

Technology is one of the weakest links in rainfed and dryland agriculture. The public sector extension system is unable to meet the demands of the rainfed and particularly dryland agriculture which is quite diverse and challenging. The only way is to build the capacity of the community based organizations and farmers groups so that the knowledge acquiring and transfer processes can go in the hands of the community. With the increasing use of ICT in rural India and several successful pilots being available on use of IT in farm extension, this method of reaching farmers is going to remain the main stay in future. From kiosk based information dissemination, we need to move more and more towards mobile based personal communication. With 3G and 4G technologies in the offing, more detailed text and pictures can be transmitted through the mobiles. Use of information technology therefore is a way to reach the disadvantaged farmers and bridge the extension gap in the country. The Institutional frameworks working in this area should strive to make best use of emerging technologies like remote sensing, geographical information systems, simulation modeling, nanotechnology, molecular biology etc. to achieve breakthroughs in technology generation in rainfed agriculture and drought management. In order to speed up the process of technology generation and reduce the lag between development and adoption of new technologies, it is necessary to use modern science tools and methods.

### **Information & communication technologies (ICTs)**

Advent of Information & communication technologies changed the global scenario in reaching the clientele. In the present era of knowledge revolution, with the advent of IT tools like computers, mobile phones and other facilities like video conferencing etc., lot of progressive dynamics are visible in human life. These ICT tools could be used efficiently for knowledge resources management in agriculture in order to address the knowledge gap among the farmers, researchers and extension functionaries.

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ICTs for rural masses was planned through establishment of KSC (Knowledge Share Centres) at grass roots level which envisages the access to value added information services on latest tools and technologies of agriculture for improving the rural livelihoods. It also facilitates the sharing of data, information and the collective knowledge gleaned from research, experiences and interaction with cluster partners.

***Simulation modeling:*** Climate change is an emerging challenge for rainfed agriculture with expected impacts on the natural resource base and the production systems. Various models predict that the impact on food crops and livestock production could be significant for the country as a whole. However, we need information on regionally differentiated impacts to enable the local governments to plan suitable adaptation and mitigation measures. Down-scaling the global climate models to regional and district level and linking with crop simulation models to arrive at crop-specific and region-specific impacts is an immediate need. Simulation models will also be used to estimate climate impacts, both current and future, on crop yields, pest and disease scenario and changes in water availability. Long range and seasonal weather forecasting can play a significant role in agro-advisories and contingency planning in rainfed agriculture. Applying these forecasts at the block and village level is a key challenge for future. Receiving weather data from automatic weather stations across the country on line and formulation of agro-advisories for micro level application and its dissemination to target areas utilizing the modern ICT tools will aid in meeting the contingencies arising out of climate variability at the farm level. This requires substantial investments in technology upgradation, networking and capacity building. Simulation models will also be used for yield forecasting at regional and national level on regular basis including the impacts of weather deviations.

### **Weather based decision support systems**

Timely decision-making from the individual farm level to the district, state and the Centre is the key in rainfed and dryland agriculture to manage risks and meet the challenges of weather aberrations. Modern IT tools can be used in managing climatic risks in rainfed areas through decision support systems (DSS). DSS is a computerized system for helping make decisions which is a choice between alternatives based on the estimates of the values of these alternatives. The Govt. of India is making substantial investments on Automatic Weather Stations. The real time weather data across the country can be gathered and analyzed by modern tools and converted into a DSS, for applications in agro-advisories, pest and disease forewarning, near real time contingency crop planning, irrigation scheduling and input use, etc. Such information could be made use for storing critical inputs like seeds through regional seed hubs and decisions on organizing other logistic support during droughts, floods and other natural disasters.

### **Role of social media in technology dissemination**

In extension, role of social media is accelerating day by day. With the ever increasing internet connectivity and cheaper tariff, mobiles and computers have penetrated in the hinterland of India. The story of Dryland areas is no different when it comes to the role of social media in disseminating the agricultural technologies. Social media refers to the means of

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interactions among people in which they create, share, consume and exchange information and ideas in virtual communities and networks. Kaplan and Haenlein (2009) define social media as “a group of Internet-based applications that build on the ideological and technological foundations of Web 2.0 and that allow the “creation and exchange of user-generated content.” Social media offers a unique way of communicating with the public because of the content that individuals can choose to engage with or not imagine that it is on a bulletin board. One of the big advantages of social media is that someone can directly respond to what you share with them. A negative is that while once something is posted it is archived and accessible far into the future, it can be quickly forgotten by those who read it because so many people have a flood of content funnelling through their social media accounts.

**Facebook:** Facebook provides users with an interactive Web page-like format to share information, photos, articles, and Web links. This venue makes it easy to post a message that can be shared with small or large communities of users. Messages, photos, and video clips can be posted easily for interested audiences (i.e., Facebook friends). Facebook attracts followers who are organizations or individuals interested in the creator’s postings. Extension educators may find it useful to communicate information regarding upcoming events, celebrations, informational pieces, and publications. A recent study about how farmers use media found that 42% of farmers who use Facebook and Twitter are using it every day. Whether sharing personal stories or using the sites as news sources, farmers are making their presence known online. Like Facebook, Kalgudi is operating in the Telangana, Andhra Pradesh etc where it is providing a platform for the farmers and other stakeholders to share a common platform. CRIDA and NICRa are having facebook pages to share and disseminate the information on rainfed technologies.

**Whatsapp:** In the recent years, Whatsapp has become a potent tool in dissemination of information. WhatsApp offers several advantages over these mobile agricultural information services. It is a form of a social media tool that enables one to many and many to many types of conversation and sharing information and facilitating discussion (Andres and Woodard, 2013). It has become the most preferred mode of communication among the smart phone using farmers. One can share information in multiple forms ranging from text-based messages to audios, visuals; audiovisual and even web links making it an information enriched platform. Additionally, information sharing is possible at any place and at any time without worrying about background disturbances (Thakur *et al.*, 2017). This tool is simpler and easy to use, has low internet data requirements, and is increasingly popular in rural India. “Shetkari Mitra” (farmers’ friend) a whatsapp group in Yavatmal, Maharashtra, has become a popular method for sharing information on agriculture. M. S. Swaminathan Research Foundation’s Village Resource Centre, created this group with over 130 farmers from different villages, who use Whatsapp. Through this group, information is shared on agriculture, marketing, animal husbandry and government schemes.

**YouTube:** YouTube is a popular video-sharing venue online that attracts millions of users daily. Extension educators find it useful to disseminate educational messages, video, and TV news clips for the global audience (Kinsey, 2010). Sharing a link to a YouTube video is simple and can easily be attached to an email message. Visual literacy (reading and writ-

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ing) is heightened for users in this interactive venue (Educause Learning Initiative, 2006). Viewer demographics (country, state, age, and gender) can be tracked, and data can be collected regarding the way the viewer found the video and information about the length of time the user browsed the Web site. YouTube's popularity makes it an attractive tool for Extension due to its viral nature, ease of use, and accessibility by audiences of all ages. Indian council of agricultural research and its various institutes have their on youtube channels where they are regularly uploading the videos. Farmers and extension professionals can download videos on important practices directly.

**Podcasts:** Podcasts are brief audio or video messages created by an individual or group and readily available on the Internet. Messages created with audio-only include the voice of the Extension educator vocally sharing his or her educational message. Audio podcasts are available at a variety of Web sites, including iTunes. Some podcasts feature enhanced video, meaning the video includes voice recording, music, pictures, and/or animation. Podcasts are useful for demonstrating how to perform a task or sharing essential research-based information. Podcasts can easily be uploaded online for sharing with the global community using video-sharing Web sites. Because users are usually well versed at locating, downloading, and playing videos that are available online, little or no instruction is generally needed. Extension educators can publish demonstrations, seminars, or workshops through podcasts (Xie & Gu, 2007).

### **Promotion of institutional arrangements for sustainable development**

In one of the project Viz., DFID-NRSP Project, the institute has come up with a innovative informer institutional arrangement called 'Salaha Samithi' (SS) consisting of representatives from all sections of the villagers Viz. small and marginal farmers, women, Panchayat Raj members, weaker sections and progressive farmers in the project areas in AP and Karnataka. Salaha Samithi has played very positive role in implementation of the project by ensuring peoples participation, which resulted in quicker adoption of technologies and provided access to the landless and poor to the natural resources for their livelihoods.

The Institute has also promoted the formulation of a Rythu Samakhya for the Ranga Reddy district and acts as a facilitator bringing together the farmers and concerned government officials to discuss the issues of farmers and provide solutions to them. These Rythu Samakhya meetings are held every first Monday of the month. The Institute has also developed collaborative links with the federation of farmers association, which is aimed at better transfer of doable technologies over wider group of farming communities.

For participatory decision making and wider adoption of climate resilient agriculture practices and also to build capacities at the local level, Village Climate Risk Management Committees known as VCRMCs were formed under technology demonstration component of NICRA.. 10 to 20 villagers came together to share, support and encourage fellow farmers to adapt to the change in climatic conditions.



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## Capacity development through custom hiring centres

CRIDA has also promoted Custom Hiring Centres (CHCs) for Agril. implements where agricultural implements are kept for hire by villagers, as small and marginal farmers cannot purchase them. They can function as a service provider and create employment opportunities for village youth. The concept of CHCs was successfully implemented in a few clusters of villages of DFID-NRSP R8192 project in AP and also in different states in India under NATP. Under NICRA project ICAR-CRIDA is promoting custom hiring centres in 121 NICRA villages through VCRMC's Village climatic Risk Management committee.

**Public-private-partnership:** The institute has also developed close linkages with private firms and NGOs for effective transfer of technologies. The institute has signed MoU's with a number of private firms for production of improved agricultural implements developed by the Institute. Similarly, Institute is also working in collaboration with reputed NGOs like BAIF, CWS, WASSAN, etc. for transferring technologies developed by the Institute.

**Market led extension:** The stakeholders in agriculture should have thorough market consciousness and a grasp of the intricacies of market oriented production techniques to be able to handle the new challenges. For this, an increasing awareness on market led extension strategies and tools is imperative. For this farmers' are to be educated and provided the necessary infrastructure like processing and value addition units. Extension function is to be strengthened because it is only by education that farmers can be made aware of the need of "low-cost," "high-quality" farming. We are witnessing the phenomena of rising input costs and falling output prices with liberalization and cheap imports. Hence, it is all the more challenging to bring about a paradigm shift in agriculture from being a mere livelihood proposition to a business activity.

## Suggestions for effective extension services

- ❖ There is a need to involve research institutes like CRIDA in formulating policies and developing guidelines for implementation of development programmes like watershed, promotion of bio-diesel plantations, credit requirements, etc.
- ❖ As the Dryland farmers resource base is poor and some of the Dryland technologies like soil and water conservation measures are capital intensive, there is a need to provide cheap financial assistance for their adoptions.
- ❖ Differential rate of interest which is below the normal rate of interest for risk prone areas/farms should be charged.
- ❖ As most of the commercial banks are burdened with other commercial transactions, it is advisable that financial institutions like NABARD and rural banks should open branches and start direct financing for agricultural purpose.
- ❖ Farmers should be made partners in technology development and assessment.
- ❖ In view of increasing use of ICT as a tool for transfer of agril. technologies, facilities should be developed for training rural youth and women in use of internet and computers.



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- ❖ Integration of private and public efforts in transfer of technologies should be developed to avoid duplication and waste of resources.
  - ❖ Consortium approach consisting of research institutes, financial agencies, Govt. development departments and NGO's should be adopted to complement the strengths of each agency for sustainable development.
  - ❖ Harness Information and communication technologies for accessing knowledge through common service centers and FIAC promoted by ATMA. Likewise, KVK at district level. Internet/cell phone/community radio as gadgets for wider outreach.
  - ❖ Coordinate efforts of various agencies to achieve synergies and convergence.
  - ❖ Public-Private-Partnership mode in the form of providing fiscal incentives, tax benefits to private organizations and private management of public infrastructure.
  - ❖ Multi-institutional efforts are suggested as a way forward to harness the relative strengths of extension, NGO, universities and the private sector.

## Conclusion

In rainfed areas, technology transfer should not only be input based but also cover soil testing contingency cropping, water conservation and livestock production. Since agriculture is becoming more knowledge-intensive, technology led, market oriented and more demand driven extension is required in a systems' perspective from production to consumption in a value chain mode. Participatory approaches in a collaborative and consortia approach in drylands alone can realize the goals towards achieving market led extension in the future. Knowledge transformation alone can bring about changes in the extension strategies in the future with application of information and communication technologies. Multi-stake holder participation through coordination and resource sharing can only shift farming into business and farmers into entrepreneurs.

## References

- Lawrence and Layle, D. 1999. Creating the future: Extensions role in Sustainable Economic development. md. II: Of Extn. Edu., 35 (1&2): 6-12.
- Andres, D. and Woodard, J. 2013. Social media handbook for agricultural development practitioners, ISBN: 0-89492-918-6, USAID Washington D.C. United States. Retrieved as <http://ictforag.org/toolkits/social/index.html#.Vrmq-1SF5dg>.
- CRIDA. 2011. VISION 2030, Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad, India, pp: 31.
- Dhan Foundation. 2006. Themes- Rain fed Farming- ,<http://www.dhan.org/rainfed.php>.6k.
- Educause Learning Initiative. 2007. 7 things you should know about Facebook II. Retrieved from:<http://www.educause.edu/ELI/7ThingsYouShouldKnowAboutFaceb/156828>

- 
- Fan, S. and P. Hazel. 2000. Should developing countries invest more in less-favored lands? An empirical analysis of rural India. *Econ. and Political Weekly* 34: 1455-1464.
- Gautam, H.R. and Kumar, R. 2014. Agricultural Development - The Road Ahead. *Kurukshetra*, 62(8): 3-6.
- <http://www.fao.org/docrep/t0060e/T0060E05.htm#Mass%20media%20in%20extension>
- Kaplan, A.M. and Haenlein, M. 2010. Users of the world, unite! The challenges and opportunities of Social Media. *Business horizons*, 53(1): 59-68.
- Katyal J.C. and Das S.K. 1994. Rainwater Conservation for Sustainable Agriculture. *Indian Farming*. Pp: 65-70.
- Kinsey, J. 2010. Five social media tools for the Extension toolbox. *Journal of Extension*, 48(5): 1-3.
- Rao, S.C. and Ryan, J. 2004. Crop Science Society of America. and Symposium on Challenges and Strategies for Dryland Agriculture. Challenges and strategies for dryland agriculture. In : Challenges and strategies for dryland agriculture. Crop Science Society of America, Madison, Wis.
- Rasheed, S.V. 2012. Agricultural extension in India: current status and ways forward. Roundtable on Agricultural Extension in Asia, Beijing, 2013: 15-17.
- Roshni, V. 2016. Dryland agriculture in India-problems and solutions. *Asian Journal of Environmental Science*, 11(2): 171-177.
- Recommendations of Working Group on Agricultural Extension for Formulation of Eleventh Five-Year Plan (2007-12), 12<sup>th</sup> January, 2007, By Working Group on Agricultural Extension constituted by Planning Commission, Government of India.
- Snapp Heong., Snapp, S.S. and Heong, K.L. 2003. Scaling up: participatory research and extension to reach more farmers. In: B. Pound, S.S. Snapp, C. McDougal and A. Braun, Editors, *Uniting Science and Participation for Adaptive Natural Resource Management*, Earthscan, UK and IRDC, Canada (2003), pp. 67-87.
- Singh, H.P., Sharma, K.L., Venkateswarlu, B. and Neelaveni, K. 1998. Prospects of Indian Agriculture with Special Reference to Nutrient Management under Rainfed Ecosystems. National Workshop on Long Term Soil Fertility Management through Integrated Plant Nutrient Supply System. IISS, Bhopal, April 2-4.
- Singh, H.P., Sharma, K.P., Reddy, G.S. and Sharma, K.L. 2004. Dryland Agriculture in India. p. 67-92. In: Challenges and strategies for dryland agriculture. Crop Science Soc of, [S.I.].
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Sixth convocation address by Dr. Mangala Rai, Secretary –DARE & DG-ICAR, at the Dr.Y.S. Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh on 16.05.2007.

Subrahmanyam, K.V. and Nagasree, K. 2006. Extension Strategies for Transfer of Dryland Technologies. In: State Level Consultation Meet on Agri-extension-29 & 30th Nov. 2006 at NABARD, Hyderabad.

Technology Assessment and Refinement through Institute Village Linkage Programme. Completion Report 1999-2004, NATP Rainfed Agro-Ecosystem, Agro-Ecosystem Directorate, CRIDA, Hyderabad.

Thakur, D., Chander, M. and Sinha, S. 2017. Whatsapp For Farmers: Enhancing The Scope And Coverage Of Traditional Agricultural Extension. International Journal of Science, Environment and Technology, Vol. 6(4): 2190 – 2201.

Xie, K. and Gu, M. 2007. Advancing Cooperative Extension with podcast technology. Journal of Extension [Online], 45(5) Article 5TOT2. Available at:<http://www.joe.org/joe/2007october/tt2.php>



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## Design Options of Portable Pumpset for Effective Utilization of Harvested Water From Farm Pond

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Farm pond is well proven technology for harvesting of rainwater and it's recycling to save crop from prolong dry spells and drought. In changing weather scenario, droughts and floods are recurring phenomenon that made greater effect on economics of farming community particularly in dryland. It is reported that decrease in yield of cereals, horticultural crops, livestock production and loss of employment all associated with decreased income of farmers are the most immediate economic impact of drought (Udumale 2014). In India, about one third of the total geographical area is drought prone, experiences drought in every second or third year. The occurrence of drought and floods is following an increasing trend over the past ten decades. Extreme events of both droughts and floods damage the crops to an extent of 60-80% specific to the areas. The erratic distribution of rainfall significantly lowers the productivity of rainfed agriculture. There are evidences that 2-3 supplemental irrigation has the potential of increase the crop yield 30-35% compared to non supplemental irrigated crops. In one of the case studies, Prasad *et al.*, 2015 reported that by using harvested water from pond for critical irrigation there was an additional yield and income from cotton (250 kg/ha of Rs 10,500), chilies (150 kg/ha of Rs 9000) and fodder grass (4 t/ha of Rs 10900). Hence, rainwater harvesting and its management assume importance in minimizing risk and stabilizing productivity in drylands.

Farm pond technology is gaining momentum as rain water harvesting structures through various government programs. The digging of farm ponds is one of the major activities under Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA), National Mission on Sustainable Agriculture (NMSA) and Rashtriya Krishi Vikas Yojana (RKVY). In many states, the financial support is extended for creation of farm ponds either in the form of loan or subsidy. Although farm pond technology is viable and are being promoted on wider scale, there are certain technical issues that limit the effective use of harvested water. The water harvested in farm ponds is relatively small and seasonal. Large number of farm ponds is created across the country under MGNREGS, but very few are being actually used for supplemental irrigation during dry spells. This is mainly due to lack of appropriate water lifting devices particularly in remote areas where electric power is not available. This chapter focuses on critical issues involved in efficient use of pond water, design options of water lifting devices, and their merits & demerits. Research at Central Research Institute for Dryland Agriculture (CRIDA) helped in identification of suitable portable pumpset for pressurized irrigation and later it was up-scaled in project mode.

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This chapter also highlights strategic plan implemented for up-scaling of portable pumpset technology and its implication on economics of rainfed farmers.

### **Critical issues for efficient use of harvested water**

The optimum use of power is about 2-3 hp for lifting of water from ponds or shallow dug wells because suction head is very low. In general, the depth of farm pond is 2-4 meter for which ideal solution would be 1.5-2.0 hp. In many places, application of water from farm ponds is severely affected where supply of electricity is difficult. Hence, from economic point of view, the pumpsets operating on diesel could be an alternate solution.

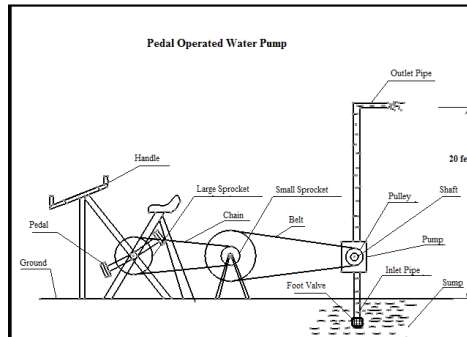
Besides availability of power source, drudgery involved in transportation of pumpset is another issue. Unlike water lifting from deep well the use of farm pond water is limited to supplemental irrigation. Usually, sprinkler irrigation is preferred over furrow irrigation because of higher water use efficiency. In market, different sizes of sprinkler sets are available operating at 0.7 to 2.5 kg/cm<sup>2</sup> working pressure. Size and efficiency of sprinklers need to be matched with low head pumpset. This requires proper understanding of the performance of low head pumpset for pressurized irrigation. Above all, farm pond based agriculture demands entrepreneurship, like custom hiring in which harvested water applied with minimum investment and also provides employment opportunity for unemployed rural youth.

### **Manual operated low head pumpset**

Various manually operated low head water lifting devices like, bicycle and pedal operated pumps are modified to improve its performance. The details of those design and performance are discussed below.

### **Bicycle operated water pumpset**

Bicycle operated pumpset consists of bicycle, rim, pulley, flywheel, and centrifugal pump as main components. The human energy required for operation of such mechanical pump is simplified with flywheel and pulley mechanism. Flywheel avoids cyclic speed fluctuations due to human power. The capacity of such pump was 2500-3000 l/h. Many researchers have studied the performance of bicycle operated pump (Sreejith et al, 2014 & Vanjari *et al.*, 2017). The schematic view of bicycle operated pump is shown in Fig 1. Vanjari *et al.*, (2017) found that such pump gave discharge about 5 m<sup>3</sup>/hr at a head of 20 m using driving torque 29.5 Nm with estimated efficiency of 90%.



**Fig 1. Schematic view of bicycle operated pump (Source: Vanjari *et al.*, 2017)**



**Fig. 2. Bicycle operated centrifugal pumpset in operation**

### **Treadle pumps**

Treadle pumps are usually pedal operated reciprocating pumps consists of piston, cylinder, rod, water seals, and pedal link. Piston is used as pressure creating component and is reciprocating inside the cylinder. Rod is used to connect the piston and foot pedal pump link. Pedal link is used to connect the piston rod and foot step mechanism. With pedal operated mechanism a person can generated four times more horsepower than by hand operated mechanism. However, continuous pedaling can be done for only short periods about 10 minutes (Sarmaraj *et al.*, 2014). Treadle pump is shown in Fig.3 which has double acting reciprocating pump. Pumping capacity of such kind of pumpsets is 0.2-0.3 m<sup>3</sup>/h.





**Fig. 3. Tradle pump**

Although manual operated pumpsets are low cost, but are not adopted by the farmers on wider scale because of drudgery in operation. There is lot of stress on knee and lower & upper side muscles of the feet. A healthy person can only reliably maintain the high- power range of about 250 Watt (Bahaley *et al.*, 2012) producing 2-3 m<sup>3</sup>/hr discharge.

### **Commercially available portable pumpsets**

Portable pumpsets are the suitable options for water lifting from farm pond as these are easy to carry from one place to another. Commonly available and most popularized pumps are centrifugal type and these are operated by engines of 1.5 to 3.0 hp (Fig. 4). The trademarks of portable pumpsets are Honda, Greaves Cotton, Edico, Kirlosker and others. Farmers have wider choice of fuel as these pumpsets are operating on petrol, kerosene and diesel. Petrol-start-diesel-run engines are of lighter weight than commonly available diesel engines for given horsepower. The essential components of centrifugal pumps are fast rotating impellor and casing. Total pressure head of these pumpsets varies from 15-30 m. Farmers have choice to select the pumpset depending upon discharge and pressure heads based on their need. Usually, higher discharge and low head pumpsets are preferred for furrow irrigation. Whereas, for pressurized irrigation high pressure head (2-3 Kg/cm<sup>2</sup>) is required. One of the limitations of centrifugal pumps is that the suction head can't be higher than 7.0 meter above the water level. However, depth of farm pond varies between 2-4 meter; therefore, such pumpsets can be recommended for lifting of water from farm pond. Regarding operation and maintenance, it requires skill which calls for training and capacity building of pumpset user. Centrifugal pumps are designed for specific flow