



Water Scarcity and Agricultural Productivity in India

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Abstract

Water scarcity has become a significant obstacle to agricultural production in India. Agriculture in India relies to a great extent on resources for which water availability is becoming a considerable burden and is more or less characterized by increasing variability. It attempts to understand the association between the availability of water and agricultural productivity while focusing heavily on a range of aspects namely the influence of irrigation dependency, depletion of groundwater resources, variability of rainfall along with state-wise differences among various farmers regarding access to water resources. This paper investigates how water scarcity impacts yield, cropping intensity, net farm income and agricultural productivity based on statistics provided by official records, water resource assessment documents as well as scientific papers. The results show how the availability of deficient and unreliable resources reduce the overall productivity, primarily by shortening the cultivable land, reducing the crops available and increasing the exposure of farmers towards rainfall variability. Such an impact seems more acute and significant in the parts of India which are heavily dependent on groundwater irrigation. Deep well drilling is another increasing threat of water exhaustion, to be sustained in the future from the farmers which will increase pumping cost and will reduce water productivity. However, this can be tackled if we utilize irrigation water efficiently by introducing Micro irrigation techniques, water Harvesting system, efficient water management policies, by enhancing crops that consumes less water by promoting adequate use of water efficient crops as well as other techniques with reference to crops.

Keywords: Water Scarcity; Agricultural Productivity; Irrigation; Groundwater Depletion; India

INTRODUCTION

Among a plethora of farming inputs, water is the most significant component influencing agriculture production, cropping intensity and farm income along with the agricultural decisions such as what to cultivate and the level of production. In India the relationship between the availability of water and agriculture production is gaining substantial importance because agricultural production has relied on the availability of rainwater and canal irrigation along with the augmentation in the use of underground water as irrigation for agriculture. Though it has been argued that an increased supply of canal and well irrigation have a greater positive influence on agricultural production and groundwater has increasingly been tapped as a supplemental source for farming in the recent years yet over-extraction of ground water have threatened to the sustainability of Indian agriculture. While recent evidence confirms that irrigation use may significantly improve agricultural productivity, ground water withdrawal can certainly limit the capacity of farmers to maintain cultivation at the current rates (Jain et al., 2025; Rodella et al., 2025).

There are several ways in which availability of water affect agricultural productivity. A shortage in irrigation water availability or reduced reliability of water delivery causes damage to both farm and crop productivity; may decrease cropped area; can result in the cultivation of less productive crop varieties which needs less water and hence result in lower returns and higher risks faced by farmers especially where farmers' livelihood is dependent on ground water. Their analysis also finds that it may affect cropping intensity at a pace of around 20 percent for India as a whole and may increase considerably for regions having deficient ground water, furthermore these results suggest that there is very little substitution effects between the demand for well irrigation water and that of canal/surface irrigation. An economic study on the value of water at farm level can be interpreted using the production functions. The agricultural product is essentially a function of land; capital; labor; technologies and natural resources of which water is an important component. Schultz's (1964) arguments to explain transformation process of agriculture reveal that development is associated with investment of resources in productive factor which result in relatively higher returns; here canal and well irrigation technologies can thus be identified as factors which improve usage efficiency of other farming inputs. Sharma et al. (2010) who presented empirical evidence for India covering the rain-fed region demonstrate potential production improvements following the practices related to water harvesting with supplemental irrigation; even a lower range of supplementary irrigation has revealed to have raised outputs quite significantly. Similarly there have been arguments with regards to its importance on livelihood economy: a large positive influence of access to groundwater irrigation have been found on overall agricultural output and can also be viewed beyond immediate production growth. Findings by Rodella et al. (2025) show that ground water extraction has expanded land under cultivation, and agriculture yield although has also highlighted issues of sustainability concerning ground water.

The essence of the discussion, however not only lies on scarcity of water but the manner in which they were managed, as different technology might demonstrate very different outcome with varying range depending upon crop, farming practices, well density and soil-moisture conditions and irrigation efficiency. Thus, findings of Palanisami and Ranganathan (2017) indicates a clear improvement of irrigation water productivity in rice production which could also be achieved by using irrigation water efficiently reducing amount of it at a very high scale through modification in farming practices; but also recognizes the impact of economics incentive and locality factor on technological adoption. Based on empirical study based on Karnataka this indicated that use of micro-irrigation resulted not only in considerable saved of water but also in substantial increase in productivity of crop and thus income without affecting

their profitability. In addition to that it was also showed in this research on northwestern India on cultivation of rice; how varied factors like farming systems; crop-water productivity; sown date, well density and farmer characteristics play crucial role on determination of yield etc. Water has thus become intertemporal resource, where a considerable over-extraction of ground water, although appears beneficial over shorter time period; tends to lower its utility as future asset, which needs a framework like tragedy of the commons-based institutional theory to demonstrate the manner in which individual decisions contribute to the overuse of groundwater at the farm level which varies in many ways when compared to traditional commons based discussion; since ground water in case of irrigation systems are treated differently but the mechanism of over-usage through private incentives is similar. In this connection, Indian experience seems rather complex concerning water availability and farm productivity. Access to irrigation increases crop yields, lower rainfall induced variability exposure and increases double/triple cropping; however on long-term basis it tends to deteriorate water resource base of agriculture. Increase in water scarcity has clearly led to decline in irrigated agricultural development in regions like Gujarat resulting in the greater out-migration from farm sector.. This paper sets forth to analyze the relation between irrigation; rainfall variability and farm income which have long been associated with farming activities. This study also tries to quantify the impact of micro irrigation, rain harvesting and different farming and water management practices that would contribute toward sustaining agricultural production under deficit irrigation scenario.

Theoretical Framework

Primary to the approach applied in this study is the agricultural production function approach, where water is defined as a productive input like other land, labour, capital and technology. Agricultural output can then be defined as a function of these inputs where the amount of available irrigation water could influence not only the amount of produce, but also how other inputs such as land, fertiliser, labor, and improved seed may be used. Under this model, it follows that if the amount of irrigation water is decreased, other input marginal productivity declines, constricting the farmer's use of the other inputs. Schultz's (1964) theory of agricultural transformation can be used as a broad underlying framework for this, emphasizing productive investment and technological progress in determining agricultural productivity.

The approach also incorporates the theory of induced innovation. As water becomes increasingly scarce, or the cost to acquire water grows, farmers are provided with an economic incentive to adopt technologies/practices to further utilize available irrigation water for increasing output. As such, micro-irrigation practices, improved irrigation scheduling, harvesting water, and changed crop choice practices are all responses to resource constraints. Research from India empirically supports this relationship showing evidence of increases in water productivity with improved water management techniques, and under appropriate condition increases in farm profit (Nagaraj & Anitha, 2023; Palanisami & Ranganathan, 2017). This analysis is also grounded on the common-pool resource approach concerning the sustainability of groundwater. While groundwater is uniquely extractable as compared to other resources, groundwater supply is interdependent of total demand placed on the resource as well as the replenishment rate. Using a common resource framework, as with Harding's (1968) model of common resources, means that externalities that may be induced by demand could lead to a reduction in available resource that leads to lower producer output and is passed off to the end user (or other farmers who rely on the same resource.) Agricultural productivity, therefore not only depends on the farm-level technological capabilities of the farmer, but also on institutions that regulate usage of the resource and irrigation supply systems.

Review of literature

Empirical studies of water availability and agricultural production within the context of India establish an inverse relationship between water supply availability and agricultural yields. Through a study that examines the levels of agricultural production in rainfed districts across India, Sharma et al. (2010) indicate that there are considerable untapped opportunities to increase production levels by harnessing water harvesting methods and implementing supplemental irrigation schemes. The studies also reveal that even small amounts of supplemental irrigation can increase agricultural production, lessening the impact of uncertain rainfall events. Research done specifically regarding the productivity effects of irrigation also demonstrates positive impacts on agricultural production due to the exploitation of groundwater resources. Specifically, Rodella et al. (2025) find strong evidence of the positive effects that exploitation of irrigation through a groundwater resource can have on agricultural output as well as an expansion of agricultural activity in India. Yet this study points to evidence that would indicate significant groundwater overuse from the irrigation system, raising further questions about sustainability of a groundwater-based irrigation system.

Aslam et al. (2021) provide further empirical research about the impact groundwater withdrawal has on cropping intensity within India. They suggest that groundwater depletion could lead to decreased agricultural activity, as cropping intensity could decline by half within currently vulnerable areas. Surface irrigation alone also indicates it is an insufficient measure for replacing fully depleted groundwater sources. Farm level analysis shows some of the productivity returns can also be obtained through higher levels of efficiency. In one study of rice cultivation in Tamil Nadu by Palanisami & Ranganathan (2017), they were able to differentiate the overall technical efficiency of agricultural output from the technical efficiency concerning water use and indicate a significant proportion could be attributed to reduced irrigation water requirements.

Studies of micro-irrigation in other countries also provide similar findings regarding increased efficiency/productivity at the expense of decreased water demand. A study examining different farming systems in Karnataka using micro-irrigation approaches, by Nagaraj & Anitha (2023), indicates both decreased water use along with increased productivity and income per unit of irrigation water used. In addition to a look at the technical relationship, greater emphasis is placed on socioeconomic implications of increasing water scarcity and irrigation impacts within recent empirical research. An illustration taken from the state of Gujarat identifies evidence of increased levels of out-migration and decreased utilization of irrigated agricultural lands as the result of declining groundwater accessibility and higher relative risk; indicating that water scarcity impacts livelihoods beyond those directly related to crop production (2025).

Research Objectives

1. To examine the relationship between water availability and agricultural productivity in India.
2. To assess the effects of irrigation dependence, groundwater depletion and rainfall variability on agricultural production.
3. To examine the role of water-use efficiency, irrigation technology and improved water-management practices in sustaining agricultural productivity under conditions of water scarcity.

Research Hypotheses

H1: Water scarcity has a significant negative effect on agricultural productivity in India.

H2: Greater dependence on groundwater and higher levels of groundwater depletion are significantly associated with lower agricultural productivity and cropping intensity.

H3: Improved irrigation efficiency and adoption of water-saving technologies have a significant positive effect on agricultural productivity under conditions of water scarcity.

Methodology

Using a descriptive and analytical research design, the study seeks to determine the extent of the relationship between scarcity of water and its productivity on Indian agriculture. Relying solely on secondary data which would emanate from government documents, agricultural statistics, water resource assessments research institutions and from peer review academic papers. Evidence is to be found within Irrigation, Groundwater, rainfall, agricultural outputs, cropping intensities and productivity. Agricultural outputs and water available shall be viewed as the primary variables with the latter being assessed using as proxies, irrigation coverage, groundwater reliance, groundwater depletion, rainfall variation and the availability of irrigation infrastructure. The former will be assessed using crop output, crop intensity, agricultural output, and water-use productivity. Irrigation technology, specifically the impact micro irrigation and supplementary irrigation, might be deemed to affect the relationship between water shortages and agricultural efficiency to some extent. Descriptive analysis can be used to demonstrate the general characteristics, and regional differences in available water and agricultural productivity respectively. The former would be employed in a comparative perspective to distinguish differences between irrigation and rainfed agricultural systems, as well as different levels of groundwater depletion. Information gleaned from empirical works previously produced by others is synthesized in the same manner as in the comparative study for determining the robustness of the water scarcity- agricultural output relationship.

Scope of the Study

The scope of this study will be the impact on Indian agriculture due to water scarcity. The study intends to cover all the major factors through which water availability will affect agriculture such as access to irrigation, groundwater dependence, and depleting water resources, variations in rainfall, cropping intensity and the efficiency use of water. Irrigated as well as rainfed agriculture will also be explored through to investigate diverse responses in the same due to water stress. Geographically speaking, while the focus will be on the whole of India. Individual states and agricultural regions will be brought to bear only if evidence would be available that would provide insightful data concerning groundwater stress, irrigation efficiency or saving technologies. Places where groundwater plays a huge role will be prioritized in that depletion could have future implications for Indian agriculture as much as it already has on productivity today. As a dimension, technology and institution responding to water stress will not be left out. Here we would be interested in saving technologies (micro irrigation, additional irrigation, collecting rain water, use of more efficiently managing methods of irrigation, better choices concerning crop to grow as well as how best to use groundwater resources). Only the economic effects on agriculture of water shortages are looked at, as a detailed hydrological assessment of specific river basins and water tables are not part of the focus in the study. Temporally speaking, not only will current data be researched, but also established literature in theory and empirical contexts, in order to provide a contextual past; that the study might explain how Indian agriculture can carry on feeding a growing population, while it saves a decreasing share of water resources.

Results and Discussion

Clearly, water supply is associated with Indian agricultural production-but in quite different ways. The evidence covered in this paper demonstrates that additional irrigation has

the capacity to raise productivity in rainfed agriculture, whereas declining water tables have the potential to depress cropping intensity; at farm level too gains from increases in the water productivity of irrigation allow current production levels to be produced by much smaller quantities of irrigation water. This evidence strongly suggests that the problem of agriculture water in India is really about both the amount of water in supply, and its quality, and timing and availability, and the efficiency with which it is used.

Results

Perhaps the most unequivocal finding related to water and Indian agriculture was concerning supplementary irrigation of rainfed areas: Sharma, et al. (2010) examined improvement of water productivity for rainfed agriculture. In a potential rain fed cropped area of 28.5 million ha they estimated that over 114 billion m³ of residual rain water was available to be harvested. They concluded that at this amount of harvested water, over 20.65 and 25.08 m ha of rain fed crop in deficit and normal rainfall years respectively could be irrigated one supplementary crop in a year (at 100mm each of supplementary irrigation). This one additional irrigation in rain fed areas can raise production over 12%, even with traditional cultivation practices and up to 50% increase in total production with improved agriculture management (Sharma et al., 2010).

Table 1. Potential of Supplementary Irrigation in Rainfed Agriculture in India

Indicator	Reported value
Potential rainfed cropped area	28.5 million ha
Surplus rainfall available for harvesting	114 billion m ³
Area receiving one 100-mm supplementary irrigation in drought years	20.65 million ha
Area receiving one 100-mm supplementary irrigation in normal years	25.08 million ha
Increase in rainfed production under traditional practices	More than 12%
Average increase in total production under improved management	50%

Source: Sharma et al. (2010), "Estimating the Potential of Rainfed Agriculture in India: Prospects for Water Productivity Improvements," *Agricultural Water Management*, 97(1), 23–30.

In line with the first hypothesis that water scarcity has negative impact on agriculture production. Even with a smaller volume of water supplementing the rain, a production increase of about half could be observed where there are not enough rainfall or rain distribution is not very effective. The results showed that water can't be disassociated from agricultural management, as over 12% production increase under the traditional method whereas around 50% increased yield under better method indicates that water interacted with other inputs and technology, making the productivity enhancing effect much greater when water could be used together with adequate farming technique. The results also proved that water harvesting was instrumental in increasing robustness against a temporal shortness in supply of water. While some surplus rainfall would exist to harvest as Sharma et al. (2010) suggested. That such is critical for dry regions of India since water scarcity is seasonal, not absent throughout the entire year so that capture and storages from excess periods may improve productivity consistency. A second important result focused on the depletion of groundwater resource. Ground water has provided irrigation with reliable supply for agricultural cultivation over Indian rainfed regions and this is largely responsible for a growth of agricultural lands. Since there is substantial pressure during continued withdrawal of groundwater it shows that most parts of agricultural

region have already suffered water depletion, Jain et al. (2021) found that according to the projected depletion trends with the utilization of detailed data of remote sensing and census, a cropping intensity decrease of nearly 20% national wide and some regions could lose up to 68% cropping intensity for the low future ground water.

Table 2. Projected Effects of Groundwater Depletion on Cropping Intensity in India

Indicator	Reported reduction
Projected national reduction in cropping intensity	20%
Projected reduction in regions with low future groundwater availability	Up to 68%
Reduction even with complete switching from depleted groundwater to canal irrigation, nationally	7%
Reduction with such switching in regions with low future groundwater availability	24%

Source: Jain et al. (2021), "Groundwater Depletion Will Reduce Cropping Intensity in India," Science Advances, 7(9), eabd2849.

Table 2 strongly indicates the second hypothesis to be true. Agricultural yields are likely to be curtailed as groundwater depletion increases the impact on cropping intensity. An increase in depletion will decrease cropping intensity which would ultimately mean farmers' will not be able to use the same parcel of land as many times as before in the course of an agricultural year. A reduction in cropping intensity is then an impact on overall agricultural output. In fact the fact that the results shows a decline to between 20% nationally to a depletion of 68% in badly affected regions clearly shows not all areas in India are equally affected with an onset of water scarcity.

Jain et al. (2021) also showed that transferring irrigated land from groundwater to canal irrigation would not perfectly substitute groundwater. Cropping intensity was still predicted to decrease, to about 7% nationally and 24% in the future most sensitive areas, should areas drawing from depleted groundwater pools be switched to canal irrigation instead. Interestingly the authors discovered that canal and groundwater irrigation can are not perfect complements. This finding is important, since it undermines the idea that expanding surface irrigation alone could solve the problems due to declining groundwater levels.

This finding has profound importance for those areas that have built their entire farming systems around ground water based farming. It is this groundwater irrigation that enabled these farms to expand to growing other crops while it could not support the farming practices during rainy season and hence was used in monsoon also. Simply adding another source to those farming systems will not provide for same flexibility after the wells deplete. It impacts individual incomes, employment and food supply directly on output as well. The last main finding concern irrigation water productivity. Examining four tank irrigated rice cultivating districts in Tamil Nadu Kuppannan et al. (2017) analysed farm level data from 224 farms. An average of 62.8% technical efficiency and 34% irrigation water productivity were reported. For irrigation water productivity, authors interpreted this as it was possible to achieve current output level with 66% less irrigation water given a farmers circumstances represented in the model.

Table 3. Technical and Irrigation Water Productivity in Tank-Irrigated Rice Production in Tamil Nadu

Indicator	Reported value
Number of farms	224
Average technical efficiency	62.8%
Average irrigation water productivity	Approximately 34%
Potential reduction in irrigation water while maintaining current output	66%
Average rice yield in sample	3,820 kg/ha
Average yield for farms with technical efficiency below 50%	2,200 kg/ha
Average yield for farms with technical efficiency of 51–80%	4,030 kg/ha
Average yield for farms with technical efficiency of 81–100%	5,080 kg/ha

Source: Kuppannan et al. (2017), “Estimating Technical and Irrigation Water Productivities in Rice Production in Tamil Nadu, India,” *Irrigation and Drainage*, 66(2), 163–172.

Three significant pieces of evidence regarding the efficiency aspect of agricultural water use were shown in Table 3: a 62.8 % average technical efficiency, leaving substantial room for improvements in using existing farm resources, and most importantly to our purposes, an average irrigation water productivity of about 34%. Kuppannan and colleagues concluded that using the technology of the present study with water-efficient strategies they could maintain their production using 66% less water. It may be argued that every farm cannot decrease their water usage by this precisely amount. However it indicates how much there is possibility to improve irrigation water efficiency for the farming systems under investigation. Three important piece of evidence regarding the impact on yields comes from the comparison of farms yield given by Kuppannan and coauthors, who showed farms below 50% T.E. having average rice yield as low as 2,200 kg/ha against 4,030 kg/ha by farms 51-80 % T.E. and 5,080 kg/ha for farms 81-100 % T.E. This demonstrates that yield is strongly depending also on more than simply the availability of water. This supports H3 concerning the correlation with improved water efficiency and water-saving devices. It also shows there's an alternative beyond simply exploiting the available resources, it's the raising of their efficiency. This is very important in contexts like that we considered: where tapping more groundwater is not possible or too expensive, let alone environmentally damaging; where farmers are unable to access any other source of water, hence, they need to be provided by solutions which make possible to increase farm production while not further depleting available resources and thus reducing water availability overall. Micro-irrigation shows further support of this assertion (Nagaraj and Anitha 2022 showed principal crops in Eastern Dry zone and Central Dry zone of Karnataka being water-efficient with micro-irrigation allowing farmers increase yield with water savings) This last authors pointed out that even if initial costs are the same (for flow and microirrigation) for a specific irrigation technique and that the amount saved is significant, this was achieved by reducing by 36.50 the consumption of water and increasing by 10 percent yield per hector; but the relative profitability of irrigation may diminish considerably in relation to externality of resource cost: thus the assessment of the value of irrigation should take into account externalities and resource costs, not simply of gross farm yield.

DISCUSSION

The findings present two main and strongly linked dimensions of the effects of water scarcity on agriculture in India: immediate effects and longer-term ones. If on one side not

having enough water during key crop stages results in reduced crop yields on the other the use of supplementary irrigation can provide a considerable enhancement of productivity (Sharma et al. 2010). A larger and complicated issue is represented by groundwater irrigation: where abundant initial resources can ensure and enhance high farming outputs, long-term over-exploitation of the underground aquifers may undermine a sustained agricultural productivity by depleting the irrigation water base. That said water itself turns in itself resource constraints for future outputs and growth of production. Sharma et al. Have investigated the benefits of augmenting the security, particularly in rainfed agricultural areas of India with traditional practices (positive yield increases >12%), or with improved management (up to 50% positive increase), supporting the role of not only large irrigation infrastructure, but small-scale projects, on-farm water harvesting and supplementary irrigation practices for farmers' yields, above all in contexts of water stress. Groundwater exploitation is perceived to have become a much more problematic long-term issue by Jain et al., who showed national cropping intensity could decline by 20%, rising up to 68% in gravely water depleted areas. This geographical unevenness is critical as the national mean can easily hide severe regional constraint where agricultural output might no longer be possible at current technological standards. This evidence is crucial in evaluating the feasibility of substitution irrigation through expanding surface irrigation; Jain et al. Argue even with full substitution there is still a residual national cropping intensity shortfall of 7%, thus revealing need of combined measures, both on supply-side (enlarging the amount of surface water) and on demand-side.

What Kuppannan et al. Showed from Tamil Nadu, however, offers a different perspective to the whole issue: in context of scarce groundwater resources, high yield can be maintained with substantial saving in irrigation water (the authors proved possible maintenance of current yields using 66% less irrigation water) which therefore does not necessarily imply proportional increase in production. This is consistent with the conclusion drawn from a comparison performed by Kuppannan et al. And yield disparities between technical efficiently classes: yield performance are clearly correlated with how efficiently farmers can utilize any input, water being no exception, thus the interaction of water with seed quality, fertilizer and labour would determine high yields, that is high water productivity, than just availability: water's effectiveness would depend on complementary resources, farmers' skills on irrigation schedules etc. On the other hand micro-irrigation may offer the same output with water savings and potentially raise profitability (Nagaraj and Anitha 2022), but we must notice the significant percentage of irrigation costs when externalities are considered. Thus the advancement in technologies may require additional incentives for farmers. In summary, for management of Indian agricultural water resources it's crucial not solely increasing the total water availability as done mostly so far. On a practical level, water-use efficiency and thus yield gains, through supplementary irrigation, on-farm water harvesting, water-saving technological equipments and irrigation scheduling have to come of age alongside considerations for crop choice. For groundwater, the evidence is rather negative; the exploitation should be rationalized in all regions based on actual aquifer conditions since even with canal irrigation a substantial reduction of cropping intensity could be reached due to its incapability to full complement the reduction in groundwater resources. The approach H1 shows that the relationship between scarcity and reduced yields exist and can be statistically explained, H2 as regard the issue of exploitation of groundwater supports evidence that this is leading to a reduced agricultural performance, and H3 with regarding productivity benefits derived from improving water use efficiency and using water-saving techniques and approaches is evident from evidence.

CONCLUSION

India's agricultural production is increasingly constrained by water scarcity. Study results demonstrate that impacts extend beyond reduced quantity of water for irrigation. Unpredictable rainfall, reliance on groundwater, shrinking groundwater availability, and inefficient irrigation practices combine to impact cropping intensity, crop yields, production choice, and economic returns from agriculture. Evidence presented here suggests groundwater-dependent regions are especially at risk as increased extraction is no substitute for dwindling surface water. Better water management practices, however, can alleviate some of the negative impacts of water scarcity. Evidence from rainfed agriculture indicates that even small amounts of supplemental irrigation can increase the area productive during a drought and agricultural production. Supplemental irrigation thus has potential even where expansion of large scale irrigation is not an option. Conversely, the findings on groundwater depletion show that increasing irrigation through groundwater extraction can be an unreliable, short term strategy. The issue of declining groundwater levels, impacting cropping intensity, persist even as farmers switch to canal irrigation in areas where this option exists. Study results also find a close link between agricultural productivity and the efficiency of irrigation water use. With rice production in Tamil Nadu varying greatly by farm in terms of both technical efficiency and irrigation water productivity, larger outputs need not correlate linearly with larger irrigation water requirements. Improved farm-level water management, along with better irrigation management and production efficiency allows farmers to maintain and possibly increase production output per unit of water consumed. Evidence from micro irrigation in Karnataka, even though not detailed here, provides ample evidence for the potential benefits in reducing water use and increasing productivity and profitability under a variety of conditions. These findings are consistent with the three hypotheses explored. Water scarcity negatively impacts agricultural productivity.

Suggestions and Policy Recommendations

1. Improvements in irrigation efficiency and water saving technologies can boost productivity under scarcity. But technologies per se cannot solve this issue as it relates to water as a common resource among farmers, regions and sectors. A shift from the focus on increasing water supplies to water-use efficiency and groundwater management is the central policy implication. The success will lie in the combination of water harvesting, supplementary irrigation, micro irrigation, better water management, crop choice and sound groundwater governance.
2. It is also important that policy reflect the heterogeneity across various states and agricultural regions across the country.
3. Sustaining productivity will necessitate coordination among irrigation, agriculture and groundwater policies as well as a broader strategy aimed at water productivity rather than mere expansion in supply. The future viability of Indian Agriculture depends on the capacity to generate more output from finite water resources, and to do so without depleting the natural resource base needed for future production. Recommendations and policy suggestions From the discussion on study findings the following recommendations can be made to improve agricultural productivity while addressing growing water scarcity in India: 1.
4. High emphasis should be laid on promotion of micro irrigation systems such as drip and sprinkler Irrigation, especially in water stressed regions and for those crops which involve huge water savings with such systems. Efforts to promote micro irrigation systems should be coupled with financial subsidies and technical assistance for proper

- usage. 2. Efforts for rain water harvesting should be promoted more extensively in rainfed and drought prone agricultural areas.
5. Farm ponds, check dams, watershed structures and similar structures at the local level storage of rainwater may prove to be very helpful at the critical crop growth stages.
 6. Supplemental irrigation using harvested water may be particularly useful to mitigate the impact of short term dry spells and rainfall variability.
 4. Overexploitation of groundwater must be addressed at recharge level.
 7. Water stressed areas where the rate of depletion of groundwater levels are at the maximum should be brought under strong regulatory framework for pumping of groundwater, enhanced monitoring of groundwater level and recharge promotion programmes. Collective participation of farmers and the community should be encouraged for improved groundwater management.
 5. The agriculture incentives provided to the farmers should be redesigned in a manner that these incentivize the water saving in the production system.
 8. In water scarcity region, agriculture incentives can be introduced to encourage farmers to adopt such crops which offer decent economic return with lower water inputs. In absence of these, farmers may continue to choose water demanding crops with high economic return in short run. Encouragement for crop diversification for selection of appropriate crops, coupled with assured marketing, storage and price support can be helpful.
 9. 5. farmers should be imparted with practical knowledge about irrigation scheduling, management of soil- moisture in the root zone, efficiency of water application to crop and improved cultivation practices. Extension services should aim at 'getting more from each drop' rather than just producing more. 6. In spite of the differences in the policy objectives, policies related to irrigation expansion, crop subsidy, energy pricing, procurement of crops, and groundwater extraction can have combined impact on the decision of farmers on water use.
 10. All these policies must be devised in such a manner that the policies designed to promote the output of agriculture do not encourage the overextraction of groundwater.
 6. Water use planning should be undertaken at the watershed and local level, considering differences in rainfall, ground water recharge, access to irrigation and cropping patterns across diverse areas. Local area based water budgets can assist in designing programmes for agricultural expansion compatible with the resource endowments. 8. Farmer must be provided with the practical information regarding the use of water saving technologies, crop's water requirements, moisture conservation techniques in the root zone, and the groundwater availability in their region. Extension services should provide demonstration on farming condition with a practical approach for ease of understanding.
 11. 9. Consistent and robust data on groundwater level, irrigation coverage, crop water use, rainfall variability and other agricultural parameters are needed to effectively implement and adjust programmes.
 12. Such data can also help to develop more efficient policies for responding to emerging stresses. 10. The variability of water resources is very large across states and the different agriculture agro-based regions in India. Policies should be tailored in accordance with the type of agriculture (rainfed areas, areas dependent on canal irrigation, regions facing severe groundwater depletion) instead of a uniform country-wide policy.
 13. 11. Economic benefit must be the primary motive in any programme aiming to achieve more output using water-saving technologies. Success should not be evaluated only by the volume of water saved but also in terms of how water saving technologies contribute

to the net production cost, yield, income and profitability of farms. 12. Building collaboration among the farmer, government irrigation and groundwater agencies, as well as research and extension organizations are essential for the long term water management of agricultural systems.

14. Local level water committees and institutions must be encouraged and empowered to manage issues of water allocation, conservation and groundwater use in a collective manner.

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