CA Discussion Paper 3

The possibilities for dryland crop yield improvement in India's semi-arid regions-Observations from the field

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Summary

This paper attempts to assess the impact of large-scale investments in soil and water conservation on dryland crop yields in three semi-arid watersheds in India. Investments in soil and water conservation are supposed to contribute to dryland crop yield improvement by rehabilitating the productive capacity of the land. On the basis of farmers' interviews, group meetings and field visits, we explore the main constraints for dryland crop yield improvement. We find that investments in soil and water conservation do not have a significant impact on dryland yields, at least not under prolonged conditions of drought. Besides, access to irrigation as a result of investments in water storage and conservation tends to lead towards more water-intensive crops instead of to supplemental irrigation to improve dryland yields. Also, we find that low production potential might not be the biggest constraint: Low economic returns, changing household diets, failing markets and poverty seem to constrain dryland crop yields even more.

Vaiju Babulgaon watershed, May 2003.

Villagers of Vaiju Babulgaon, working on soil and water conservation, May 2003.

1. INTRODUCTION

In India, dryland agriculture[1] accounts for nearly two-thirds of total cropped area and generates nearly half of the total value of agricultural output (Kerr 1996, Rosegrant et al. 2002). This paper specifically focuses on dryland agriculture in semi-arid regions. In these regions, around 300 million people depend for their sustenance on dryland agriculture, of whom 30-40% can be classified as poor (Ryan and Spencer 2001) Although in the last decades the yields of dryland crops have increased, they are still much lower than the yields of irrigated crops: In 1970 the value produced per hectare in irrigated agriculture was on average 60% higher than that in dryland agriculture, but by 1994 the difference had gone up to 78% (Fan et al. 2000). Improving dryland crop yields is important, both to maintain food security and to improve the livelihoods of the poor (Ryan and Spencer 2001). Also, with a depleting resource base[2] and with stagnating productivity in irrigated areas, improving the productivity of dryland agriculture is necessary to maintain food security at the national scale.

Results from agricultural experimental stations show that substantial improvements in dryland crop yields are possible (Wani 2001, Rockstrom and Falkenmark 2000, Singh et al. 2001). However, to improve yields investments are needed in three fields (Rosegrant et al. 2002). First, the agricultural production potential of the land needs to be improved. Low and erratic rainfall, poor or steeply sloped soils and a short cropping season make the uncertainty of dryland agriculture in semi-arid regions high. To improve the conditions for agricultural production, investments are needed in soil and water conservation to improve soil fertility, increase soil moisture and allow for supplemental irrigation in critical stages of growth (Keller et al. 2000, Oweis et al. 1999). Second, investments are needed in crop variety improvement to reduce vulnerability to pests and diseases and increase yields through improved production techniques (Ryan and Spencer 2001). Third, investments in infrastructure are required to reduce the costs of agricultural production and improve the socio-economic conditions for agricultural production in semi-arid zones (Fan and Hazell 2001). Although, ideally, investments would be made in all three areas, with limited budgets the question is what poses the main constraint? In India, the choice has been to invest in soil and water conservation, to improve both the conditions for dryland agriculture and provide employment in times of drought[3].

This paper attempts to assess the impact of this strategy on dryland crop yields. We selected four villages in India's semi-arid regions to interview farmers and visit their fields. To account for the different factors inhibiting dryland crop yield improvement on-farm, we selected villages on the basis of their natural production potential, investments made in soil and water conservation and irrigation access and level of integration in the market economy. Although data were available regarding crop production, household characteristics and investments in soil and water conservation, the fact that we only had access to data for one (drought) year and that time-series hydrological data were missing resulted in a situation where we depended mostly on farmers' perceptions for our results. At the sites, one-year hydrological, remote sensing and household survey data had already been collected through the LEAD project[4].

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[1] In this paper we define 'dryland' agriculture as agriculture with less then 30% of the area irrigated (ICRISAT 1998). 'Dryland' crops are those that are primarily grown under rainfed conditions with minimal or no irrigation, like millet, sorghum and pulses. We distinguish these from semi-irrigated crops (oilseeds, horticulture) and irrigated crops (rice). Although these definitions might seem arbitrary, given that dryland millet and sorghum can be and in some cases are irrigated while rice may receive little or no irrigation if prevailing climatic and soil conditions are adequate, in the semi-arid regions that are the focus of this paper, sorghum and millet are typically dryland and rice, oilseeds and horticulture (partly) irrigated crops.

[2] See for example ICRISAT (2001), Rosegrant et al. (2002) and the proceedings of the IWMI-Tata Water Policy meetings on www.iwmi.cgiar.org/iwmi-tata/

[3] Watershed development is in fact one of the main programs for rural development, with an annual budget of approximately 500 million USD (GOI 2000).

[4] The 'Livestock Environment Interactions in Watersheds' (LEAD) project, a study undertaken by IWMI and NGO partners between 2002 and 2004, financed by the Swiss Development Cooperation (SDC) and the Food and Agriculture Organisation (FAO).

Additional data were collected by the non-governmental organizations that implemented watershed development at the study sites. Data were collected in three steps. First, secondary data on cropping patterns and land and water use were collected from the agricultural extension and local revenue offices (*mandal or taluk*). Second, individual households were interviewed about factors constraining agricultural production. Third, village meetings and field visits took place to further discuss the constraints. Secondary data and LEAD study reports were used to characterize the study sites in terms of agricultural production potential. We defined agricultural production potential as a combination of the natural conditions present and the investments made by farm households and others to improve the production capacity of the land. In the next section we present the study sites. In the third section we elaborate the impact of soil and water conservation investments and in the fourth section we analyze the constraints for dryland crop yield improvement with the results from farmers' interviews, case studies and household surveys. The fifth section concludes the analysis with the findings that 1) watershed development does not show a significant effect on dryland crop yields under prolonged drought conditions, 2) access to irrigation as a result of watershed development tends to lead towards more water-intensive crops instead of supplemental irrigation of dryland crops, and 3) low agricultural production potential does not seem to be the main constraint for dryland crop yield improvement in India's semi-arid zones.

2. THE STUDY SITES

The sites were selected at the meso-watershed scale[5] based on differences in biophysical characteristics, investments made in soil and water conservation and the characteristics of the local economy. Figure 1 presents the location of the study sites, and table 1 summarizes the main characteristics.

Figure 1. Location of the study Sites.

[5] Meso-scale watersheds differ from the usual scale of watershed implementation. Meso-scale watersheds (5,000-10,000 ha) are defined by the boundaries of the watershed, whereas micro-scale watersheds are defined by village boundaries to facilitate implementation.

Table 1. Characteristics of the study sites.

	Cash based economy	Subsistence economy
High rainfall	Kosgi, Mahbubnagar district, Andhra Pradesh (4890 ha, 4242 households)	
Low rainfall	Vaiju Babulgaon, Ahmadnagar district, Maharastra (3472 ha, 1298 households)	Kanakanala, Koppal district, Karnataka (13402 ha, 2643 households)

Table 2 shows for 2002 the average crop yields of the study sites, the district averages and the experimental yields. In all three sites, the gap with experimental yields is large. Also, productivity in the study sites is lower than at the district scale. This might be explained by the fact that watershed development projects are usually targeted at the more marginal areas with lower yields. Kosgi watershed is an exception.

Table 2. Crop yield data (kg/ha).

Watershed	Crop (season)	Field level (kg/ha)	District level (kg/ha)	Gap district yield	Experiment station (kg/ha)	Gap experimental yields
Kosgi	Millet (monsoon)	-	412	-	1612	-
	Sorghum (post-monsoon)	753	614	NA	1955	1202
Kanakanala	Millet (monsoon)	305	572	267	905	600
	Sorghum (post-monsoon)	234	648	414	1386	1152
Vaiju Babulgaon	Millet (monsoon)	375	625	250	1612	1237
	Sorghum (post-monsoon)	40	427	387	1465	1425

Source: LEAD household survey 2003 and district statistical handbook (2002). Experimental data provided by Dr M.V.R Murty (ICRISAT), personal communication. Experimental data apply to the entire state.

There are basically three factors that explain variations in crop yields: 1) the conditions for agricultural production or the production potential of the land, 2) the socio-economic environment and level of market integration, and 3) the type of crops, seeds and production techniques used. In this paper, we focus on the first two factors. However, in the analysis of production constraints we will address the availability of high yielding varieties, agricultural inputs and production techniques as well.

Table 3. Agricultural production potential.

Watershed	Annual rainfall	Tanks (storage)	Irrigation sources/depth	Irrigated/ total area	HH with irrigation	Av. land holding (ha)	% area slope >5%
Kosgi watershed	739 mm	11 (133 mm)	Tubewells 250 ft	30%	50%	0.6	0
Vaiju Babulgaon watershed	430 mm	13 (16 mm)	Open wells 30 ft	10-15%	84%	1.5	42%
Kanakanala watershed	499 mm	4 (9 mm)	Tubewells 150 ft	1-5%	19%	5	17%

Source: De Putter, J., (2004) & LEAD household survey 2003 data.

As table 3 shows, the conditions for agricultural production are most favorable in Kosgi watershed, with relatively high rainfall, low aridity and flat lands. Investments in water storage and irrigation are also relatively high, but average landholding is small and groundwater over-exploitation has caused groundwater levels to fall. In Kanakanala, conditions are much less favorable, with high aridity, sloping lands and low levels of water storage and irrigation. Average landholding is relatively high, but agriculture is relatively extensive with few households having access to irrigation. In Vaiju Babulgaon, the conditions for agricultural production are relatively unfavorable with high aridity and sloping lands. However, considerable investments in irrigation have improved the production potential of the land. Contrary to Kosgi and Kanakanala, irrigation here takes place through (shared) open wells. The advantage is that the costs of open wells are much lower than those of borewells, allowing more people to have access to groundwater[6]. However, open wells are also shallow and tend to dry up in times of drought. Soil quality and depth are highly variable within the watersheds. Black soils are generally more productive than red soils, because of their high soil moisture retention capacity and higher fertility. In each watershed both red and black soils exist, but since no soil maps were available, the distribution of soil type, depth and fertility is largely unknown.

With regard to investments in soil and water conservation, in Kosgi and Kanakanala traditionally, investments in soil and water conservation were low. In Vaiju Babulgaon households are more used to invest in soil and water conservation and even in non- project villages considerable investments are made[7]. In all three watersheds public investments in soil and water conservation were undertaken, but, as the data in table 4 show, by different organizations and in different ways.

Table 4. Watershed investments in selected villages.

Watershed	Implementing agent	Study village	Investment in village	Costs/ha*
Kosgi watershed	Drought Prone Area	Potreddipalli Programme (GO)	Rs 250,000	Rs 1000/ha
Vaiju Babulgaon	WOTR (NGO)	Vaiju Babulgaon	Rs 5,210,868	Rs 5000/ ha
Kanakanala	SAMUHA (NGO)	Idlapur (Phase 1)	Rs 750,000	Rs 1600/ha
		Garjanal (Phase 2)	Rs 150,000 (on going)	Rs 100/ha (just started)

* For Idlapur, Garjanal and Potreddipalli data on treated area were missing, so total area data were used

In Kosgi, implementation was finished in 2001 and investments were undertaken by the government. During project implementation little time was allocated to stakeholder involvement and few families actually benefited from the program. Overall, few investments in resource conservation were made and the quality of investments was low. In Kanakanala, the NGO SAMUHA implemented watershed development. Phase I was finalized in 2001, Phase II is still ongoing. Investments focused on increased soil moisture and biomass, erosion reduction, and improved access to supplemental irrigation. Implementation is participatory and investments in local institution and capacity building are being made. Although, because of the size of the watershed, investments per hectare are relatively low, the quality of investments is high and most villagers have benefited in one way or the other. In Vaiju Babulgaon, the NGO Watershed Organisation Trust (WOTR) finished watershed development

[6] Access to irrigation not only differs between the watersheds, it differs within a given watershed too. In Kanakanala for example, no household in upstream Idlapur can get access to irrigation because water levels are too deep, whereas in downstream Garjanal even poor households invest in borewell irrigation.

[7] An explanation might be that most of the land is relatively sloped and that the population density on the flatter lands is relatively high. The homogeneous, high caste farmer population of Vaiju Babulgaon watershed could be another explanation.

in 2002. Investments were targeted at reduced soil erosion, increased biomass, well recharge, increased soil moisture, crop diversification and access to supplemental irrigation. Implementation was participatory and extensive investments in local institution building were made. The quality and level of investments was high and most villagers benefited considerably.

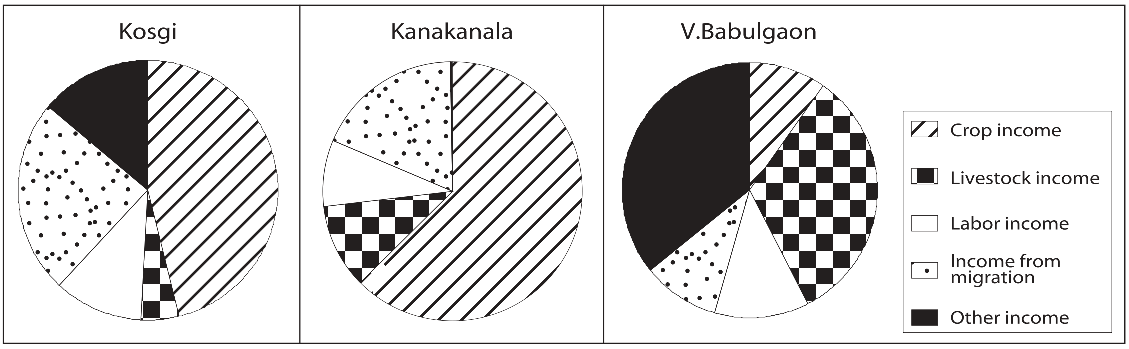
Table 5. Household characteristics.

	Kosgi	Kanakanala	Vaiju Babulgaon
No. of observations	203	200	200
Average income per capita (Rs)	2,824 (3,752)	2,531 (1,825)	10,668 (8,172)
Average education of HH (years)	3.12 (2.38)	1.61 (1.71)	5.14 (2.41)
Average landholding (ha)	1.24 (2.05)	3.56 (3.10)	2.16 (3.14)
Average irrigated area (ha)	0.50 (1.29)	0.37 (1.10)	0.15 (.40)
HH with access to irrigation (%)	50%	19%	84%
Gini income	0.44	0.36	0.37
Gini land holding	0.50	0.39	0.49

Source: LEAD household survey 2003. The figures in parentheses are standard deviations.

In terms of socio-economic conditions, the level of overall development is lowest in Kanakanala watershed, as the relatively low average income and years of schooling show. In Kosgi, the economy is more developed, but here inequality is relatively high. This can be seen from the high Gini coefficients, for both income and land. In Vaiju Babulgaon the level of economic development is the highest and the benefits of development have been more equally shared. Both Kosgi and Vaiju Babulgaon are well integrated into the market economy. Farmers use externally purchased inputs and high yielding varieties and a larger share of income is derived from non-agricultural sources[8]. In Kanakanala most income is derived from (dryland) crops and few inputs are used.

Figure 4. Distribution of household income over different sources.



Source: LEAD household survey 2003.

Since most dryland crops are grown as subsistence crops, the more a region is integrated in the market economy the less households are usually inclined to grow dryland crops. For example, in Kosgi watershed (a cash economy), over the last decade farmers reduced the area of sorghum and millet from 60% of the total area to less than 30% , to grow more rice. On the other hand, in Kanakanala (a subsistence economy) sorghum and millet are grown on more than 60% of the land. The case of

[8] In Kosgi as inequality is relatively high, (poorer) households mainly depend on wage labor whereas (richer) households mostly depend on crop income.

Vaiju Babulgaon is different: Although this watershed is strongly integrated in the market economy, the production of sorghum and millet still accounts for more than 90%. The main reason for this is fodder production. Dairy livestock being the main source of income, households cultivate sorghum and millet partly for the crop residue. Also, changing household diets influence the popularity of dryland crops. In Vaiju Babulgaon the main diet consists of sorghum and wheat chapattis, whereas in Kosgi and Kanakanala the staple food is rice, and sorghum and millet are considered poor people's food[9]. In Kosgi, only finger millet (*ragi*) is cultivated to a certain extent, because the market price is good. In Kanakanala, lack of water prevents households from growing rice, but whenever farmers can afford it they diversify to (the cash crops) sunflower and gram instead.

Hence, although poor natural conditions are undoubtedly a limiting factor, the main constraints for dryland crop production seem to lie more in the realm of socio-economic constraints. If this is indeed the case, the impact of soil and water conservation on dryland crop yields might be limited, since as soon as conditions improve farmers can be expected to change the composition of their crops.

3. IMPACTS ON DRYLAND CROP YIELDS

The impact of well-implemented watershed projects on dryland crop yields can be significant (Kerr et al. 2002, Wani et al. 2002, 2003). Due to increased soil moisture, the yields of dryland crops increase; bunds, weirs and drainage line treatment decrease soil erosion; and check dams and percolation pots improve groundwater levels. Unfortunately, with regard to the impact of the investments in the study sites, data on hydrological impacts and multi-year crop productivity are lacking. Hence, we depend on farmers' perceptions to assess how watershed development has affected the productivity of dryland crops.

In Kosgi, farmers indicated that investments mainly benefited groundwater levels near tanks. Dryland farmers did not benefit from the watershed development program since no measures were taken to increase soil moisture on their lands. In Kanakanala's Phase 1 villages, crop yields reportedly increased by 30-50% (Samuha 2003). In Phase II villages investments are still ongoing but farmers say that upstream investments benefited them by increasing the groundwater flow. In Vaiju Babulgaon, crop yields increased for both dryland and irrigated crops. Whether these crop yields increased because of increased soil moisture or increased use of agricultural inputs is not clear since both fertilizer and pesticide use increased considerably over the same period of time. Also, watershed development allowed farmers to shift to higher value crops, like vegetables and fruit as the irrigated area increased from 8% of the total cropped area to 21% (WOTR 2003).

From the accounts of villagers, the main effect of watershed development seems to be an increase in groundwater levels. Although crop yields reportedly improved as well, farmers indicated that not all households benefited since returns to investments on private land were relatively low. The main beneficiaries were farmers close to drainage lines and check dams, as for these farmers soil moisture significantly improved. The investments in bunding, trenching and boulders reduced soil erosion, but did not improve soil moisture much. Also, farmers with black soils benefited more, as their soils better absorbed the additional water. Farmers did indicate that results could be an underestimation because of the extended drought. After implementation rainfall had been below normal and many farmers confided that results had not yet been seen.

[9] In Kosgi and Kanakanala also, sorghum and millet used to be the staple food, with rice reserved for the rich. With decreasing (i.e highly subsidized) rice prices, households shifted to the consumption of rice, turning sorghum and millet into a so-called 'Giffen good' (Ray 1999).

3.1. Supplemental irrigation

Although, initially, the idea of watershed development was that increased groundwater levels would allow for supplemental irrigation in times of drought (Oweis et al. 1999), from the conversations with farmers it seemed that households with access to irrigation were more inclined to use the water for higher value, more water-intensive crops. From an economic perspective, this makes sense, as the profitability of dryland crops is low. However, from a hydrological perspective it means that scarce water resources are used for less, but more water-intensive crops. This might improve water productivity, but it does not improve the yield of dryland crops. In some cases, the extra water available for irrigation actually seems to have worsened the conditions for dryland agriculture, as wells initially used for supplemental irrigation began to be used to fully irrigate more water-intensive crops (Batchelor et al. 2003). Although we did not see this happen in the study sites, the more general trend of farmers shifting to groundwater irrigation definitely affected dryland agriculture in a negative way.

To check whether farmers with access to irrigation indeed tend to shift to more water-intensive crops, we estimated the probability that households grow dryland crops on a plot with access to irrigation. The methodology used is a probit analysis, which determines the probability that a household with irrigation grows a dryland crop (=1) or not (=0). Data were collected in 2003 as part of the LEAD household survey.

Table 6. Factors determining the choice for dryland crops (sorghum/millet/gram).

	Monsoon		Post-monsoon	
	Probit estim.	Marginal effects	Probit estim.	Marginal effects
Constant	.22 (.26)		-.13 (.31)	
Kanakanala#	2.08 (.26)	.35 ***	1.13 (.25)	.35***
Vaiju Babulgaon#	1.79 (.24)	.30 ***	1.7 (.29)	.42***
Access to irrigation*	-.59 (.21)	-.12 **	-.65 (.25)	-.21 **
Amount of irrigated land (ha)	-.73 (.12)	-.15 ***	-.55 (.15)	-.18 ***
Distance from homestead (km)	.21 (.12)	.043	.22 (.11)	.07 *
Soil fertility#	-.42 (.18)	-.09**	-.35 (.17)	-.11*
Investment in S&W#	.01 (.18)	.003	.31 (.19)	.10
Plot size (ha)	-.008 (.03)	-.002	-.08 (.05)	-.03
Slope #	.10 (.18)	.02	.49 (.18)	.16**
Number of observations	479		352	
Log likelihood	-144.5		-144.8	
Pseudo R2	.43		.31	
LR chi2 (df)	217.38		136.00	

\# dummy variable. Figures between parentheses are standard deviations. *10% **5% ***1% significant.

As we can see from the results presented in table 6, households with access to irrigation tend not to grow dryland crops. First, this becomes apparent from the significant negative effect access to irrigation has on the choice for dryland crops. Second, as compared to Kosgi watershed, in Kanakanala and Vaiju Babulgaon, with less irrigation, the probability of households growing dryland crops is higher. The impression that the choice for dryland crops is a negative choice is supported by the result that households with access to fertile soils prefer not to grow millet and sorghum, soil fertility having a significant negative effect. The results presented in table 7 confirm the observation that when farmers have access to irrigation they tend to shift to more water-intensive crops.

Table 7. Factors determining the choice for semi-irrigated crops (oilseeds/horticult.).

	Monsoon		Post-monsoon	
	Probit estim.	Marginal effects	Probit estim.	Marginal effects
Constant	-2.3 (.30)		-.83 (.31)	
Kanakanala#	.43 (.28)	.05	-.05 (.25)	-.01
Vaiju Babulgaon#	.45 (.29)	.06	-.67 (.27)	-.16 **
Access to irrigation#	.52 (.25)	.06*	.73 (.26)	. 20**
Amount of irrigated land (ha)	.30 (.08)	.03***	.43 (.13)	. 13***
Distance from homestead (km)	-.02 (.13)	-.002	-.18 (.11)	-.05
Soil fertility*	.27 (.18)	.03	.05 (.17)	.01
Investment in S&W#	.003 (.19)	.0003	-.23 (.18)	-.06
Plot size (ha)	-.01 (.03)	-.001	.05 (.03)	.02
Slope #	-.24 (.20)	-.03	-.48 (.17)	-.13**
Number of observations	479		352	
Log likelihood	-115.7		-152.5	
Pseudo R2	.13		.19	
LR chi2 (df)	34.07		72.23	

dummy variable. Figures between parentheses are standard deviations. *10% **5% ***1% significant.

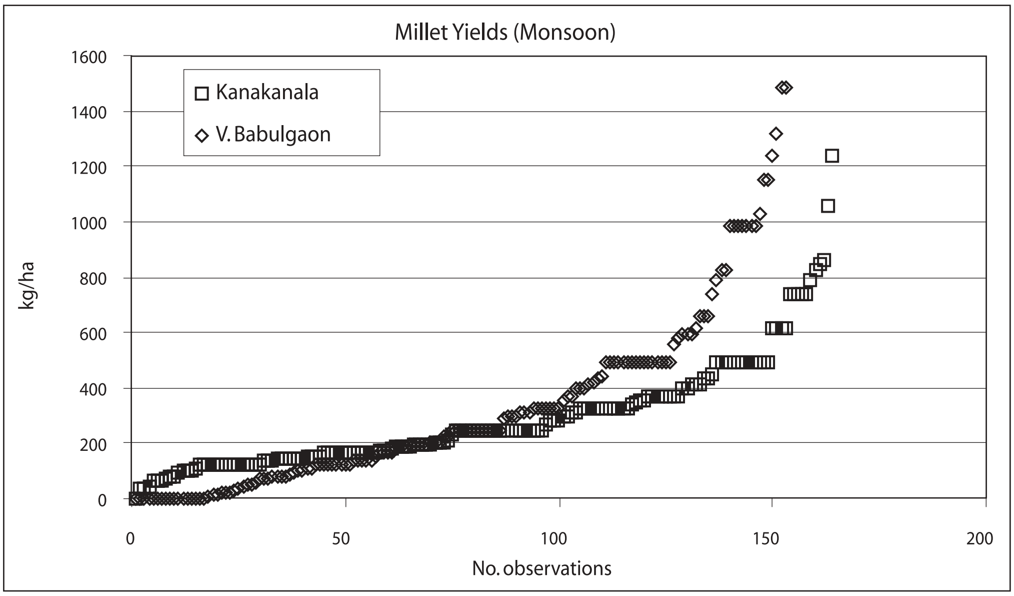
Even if farmers would want to use supplemental irrigation to improve the yield of their dryland crops, the high cost of irrigation (especially in case of borewell irrigation) prohibits the use of water for low return crops. Farmers in Garjanal explicitly said that in order to pay back the money lender they had to grow three sunflower crops a year. In Vaiju Babulgaon however, farmers do occasionally irrigate dryland crops, using shared, open wells that have already been paid back. The presumed use of supplemental irrigation to stabilize dryland crop yields in times of drought is also limited by practical constraints. Farmers said that even if they wanted to use supplemental irrigation to save their dryland crops, this was not possible because of the slope and location of the land. Since farmers tend to plant dryland crops on the more uphill, sloping plots, in order to save these crops with supplemental irrigation, large investments in irrigation pipes and pumps would need to be made.

Hence, the impact of watershed development on dryland crop yield improvement in the project sites seems rather disappointing. Although farmers with lands close to drainage lines or check dams did report that the yields of their dryland crops increased, for more uphill farmers with red soils and no access to irrigation, the reported benefits were low. One reason for the disappointing result could be the prolonged drought. However, the pattern of farmers with access to irrigation benefiting more than dryland farmers has been confirmed in other studies as well (Farrington et al. 1999, Kerr 2002). Especially in villages where the distribution of irrigation access is highly skewed, watershed development seems to have contributed little to improve dryland yields. In the next section we will elaborate on some of the other reasons for low dryland yields.

4. FARMERS' PERSPECTIVES ON YIELD GAPS AND PRODUCTION CONSTRAINTS

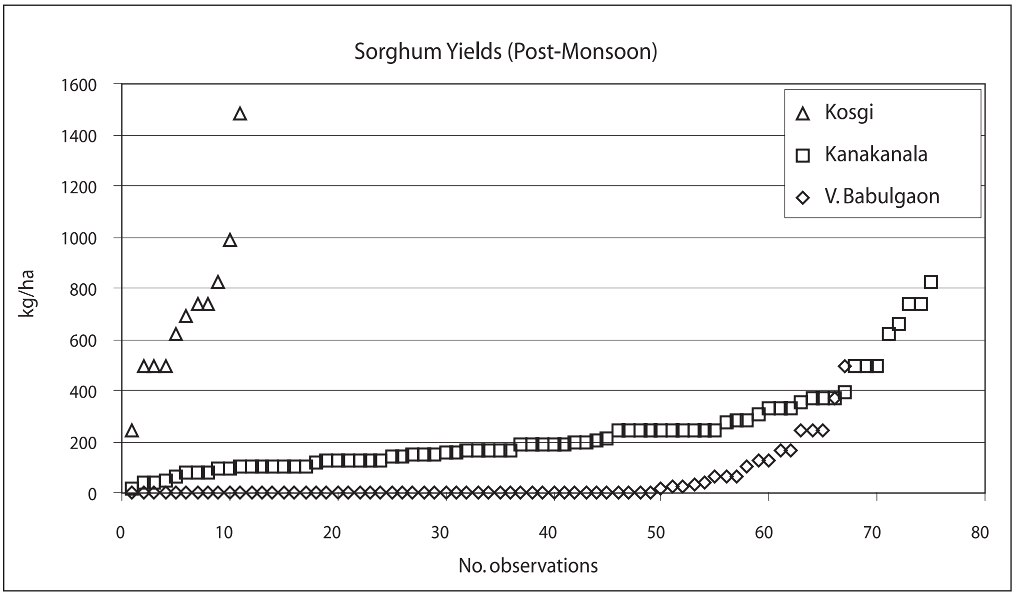
If farmers don't use their improved resources on dryland crops, the question arises as to how dryland crop yields can be improved. After all, farmers with access to irrigation might choose to grow more water-intensive crops, but for those with no access improving dryland yields remains important. Besides, with declining groundwater levels, the move towards more water-intensive crops might need to be reversed (Rosegrant et al. 2002). In some regions, groundwater levels have dropped to 300 feet and are unlikely to be recharged in any time close. Hence, we asked farmers about the main constraints to improve yields on their dryland plots. That considerable variation in dryland crop yields exists becomes apparent from the figures given below.

Figure 2. Millet yields (Monsoon).



Source: LEAD household survey 2003.

Figure 3. Sorghum yields (Post-Monsoon).



Source: LEAD household survey 2003.

The variability in crop yields is large, with yields ranging from 0 kg/ha (mainly due to crop failure) to 1500 kg/ha for both sorghum (post monsoon) and millet (monsoon). However, these figures are distorted due to the prevailing drought. Especially in Vaiju Babulgaon, after three years of consecutive drought, agricultural productivity is extremely low. Interestingly, crop yield variability is higher in Vaiju Babulgaon and Kosgi than in Kanakanala, which might be an indication of a higher variation in input use and production techniques. In all sites, farmers indicated that yields were relatively low because rainfall and the predictability of rainfall had declined over time. Whether this claim is true could unfortunately not be tested, but the general perception is that due to climate change rains are less and more unevenly spread. Although not explicitly mentioned, this seems to constitute another reason why farmers so desperately want access to groundwater irrigation. With no access to irrigation, the risks of agricultural production are high and with small landholdings a proper livelihood is hardly gained.

Farmers in Idlapur, Kanakanala mentioned lack of means and lack of access to improved varieties as the main constraints. They said that whereas on experimental fields all inputs are supplied, in real life farmers are forced to limit inputs to what they can afford. Also, agricultural innovations and high yielding varieties do not reach farmers and with stagnant crop outputs and increasing costs it is becoming increasingly difficult to maintain a livelihood primarily based on agriculture alone[10]. What the farmers did not mention, but what they implicitly made clear, was that they are not interested in growing dryland crops. On the offer of one of the authors to send an expert of ICRISAT with improved varieties of sorghum and millet, farmers responded they were not interested in sorghum and millet but wanted to grow chillies and medicinal plants, instead. The reason seems to be that farmers want to earn cash income and move away from traditional crops.

In Vaiju Babulgaon financial constraints were mentioned less. Only with regard to investments in irrigation and land leveling did farmers mention inability to invest sufficient resources, but for most households access to capital was no issue at all. Interestingly, rising costs of labor was no issue either, farmers still paying Rs 30/day ($0.67). Low migration rates and the homogenous population of Vaiju Babulgaon watershed might be an explanation. Also, farmers have better access to agricultural innovations. A crucial difference is that most households have access to a steady source of cash income, be it in terms of a government job, dairy income or state pension. As a result, most farmers can make investments in the production capacity of their land. Also, external service provision is better in Maharashtra. Agricultural extension is provided in the villages, while seeds, credit and inputs are available through farmers' cooperatives. Hence, the main constraint in Vaiju Babulgaon was the weather and lack of rainfall for the last 3 years.

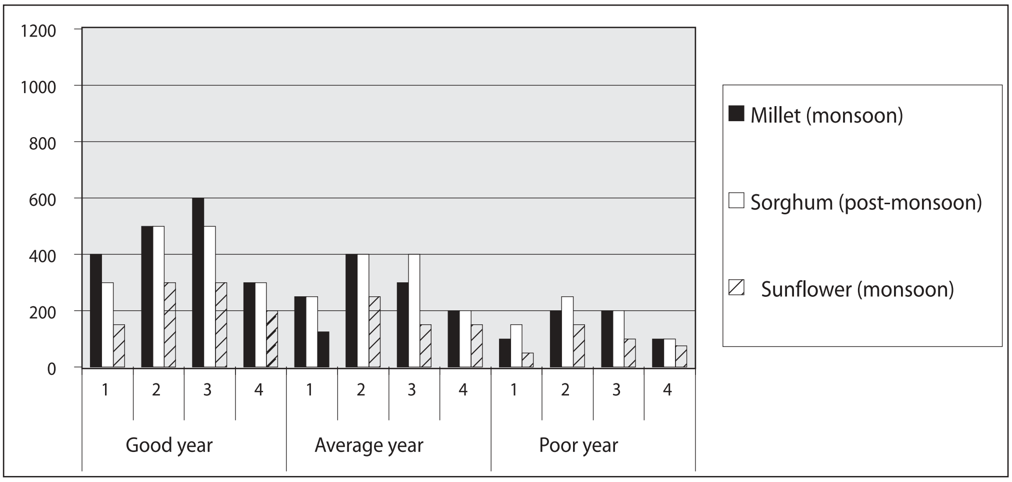
In Kosgi, farmers mentioned lack of access to improved varieties and agricultural inputs as the main constraints. Pest attacks and lack of access to supplemental irrigation were other factors mentioned to explain the low yields of dryland crops. Increased costs of production were also a problem, especially labor costs. Most farmers with no access to irrigation migrate during post-monsoon season, with the side effect that the remaining farmers are left with a shortage of hands. The few non-irrigating farmers we spoke to had alternative sources of income, and did not depend exclusively on dryland agriculture for their livelihood. Investments in dryland agriculture in Kosgi were very low, especially when compared to the other sites.

[10] For example, agricultural labor used to cost Rs 25/day ($0.56), but with increased migration and off-farm employment opportunities, laborers now demand Rs 50 ($ 1.10).

4.1. Poverty, resource access and the variation in crop yields

When discussing with groups of farmers, it was mainly the more successful farmers who spoke up. However, from the individual farmer interviews and field visits we got the impression that it was especially the poor and marginal who depended on dryland crops. To get a good picture of the differences between farmers, in terms of agricultural production, production potential and constraints, we interviewed 5 types of farmers in each study site. Farm types were defined on the basis of landholding size and capacity to innovate. In all sites, the most affluent, innovative farmer produced fruit, vegetables or flowers for the local market. The most marginal farmer on the other hand grew only millet and pulses during monsoon season and migrated the rest of the year. Few exceptions to this general pattern were seen. One landless laborer in Vaiju Babulgaon gained enough through watershed development wage labor to buy 7 acres of red soil land. One average size farmer with a little shop in Garjanal experimented with horticulture plants and vegetable crops. Overall, however, the general pattern of more well-off, risktaking cash-crop farmers versus more marginal, migrating, subsistence farmers proved to be an accurate characterization of the livelihood strategies found. The level of the average farmer did differ between watersheds and villages. The average farmer in Vaiju Babulgaon and Kosgi has access to irrigation, but the average farmer in Idlapur and Garjanal does not.

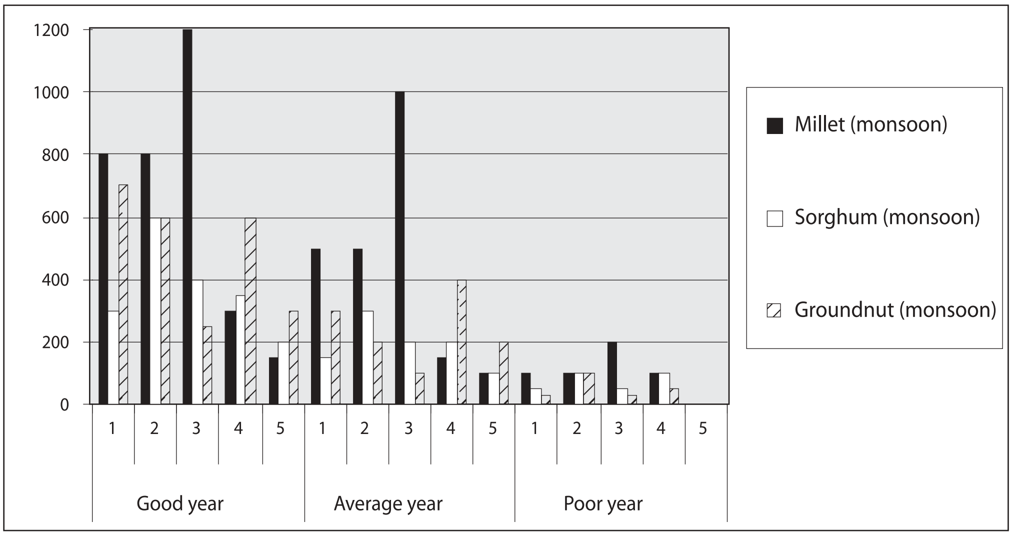
Figure 5. Crop yield differences between farmers in Idlapur, Kanakanala.



Source: Farmer interviews.
No. 1 represents the most well-off household and no. 4 the household with the smallest landholding.

As an illustration we present crop yield differences between farmers in Idlapur, Kanakanala in figure 5. We see crop yields going up for farmer 2 and 3 and going down for the more marginal household no. 4. In the case presented, farmer 1 has concentrated fully on his cash crop (*Kanakambar* flowers), neglecting the dryland crops he grows on other plots. Farmer 2 however manages to increase the productivity of all his crops by leveling his land and investing in soil fertility and moisture. Irrigation is only used for cash crops. Farmer 3 does not have access to irrigation, but her land is located near a check dam and she has deep black soil. Investments in bunding, stone weirs and river bunds have further increased the productivity of her land, and according to the farmer, millet yields have increased fourfold. Farmer 4 also has rich black soil, but he has no access to water and his land is also slightly sloped . He would like to invest in a farm pond, but lacks the funds (and initiative) to do so. For farmer 5 no crop yield data were available, but his land consisted of very poor red soil and he explained that he migrates most of the year since he cannot gain a proper income from his land.

Figure 6. Crop yield differences between farmers in Vaiju Babulgaon.



Source: Farmer interviews.
No. 1 represents the most well-off household and no. 5 the household with the smallest landholding.

In figure 6, a similar picture arises for the 5 farmers types in Vajiu Babulgaon. Farmer 1 is a very successful farmer who owns 13 acres of land, 2 borewells and 3 open wells. He has invested in drip irrigation to grow fruit for the market and other crops. He grows sorghum on his black soil and uses supplemental irrigation if water is available. Farmer 2 is a recent, but very innovative farmer, who has poor soil but who has invested considerably in the capacity of his land. He has access to an open well, but usually uses the water only for his cash crops (pomegranate and onion). Farmer 3 grows only dryland crops and uses supplemental irrigation to improve yields. Farmer 4 is a widowed lady, who shares a well and grows mainly subsistence crops on her land. Farmer 5 is a laborer, who most of the time works on other people’s land.

Based on the interviews, there seem to be six factors through which household characteristics affect agricultural production and dryland yields. First, household characteristics determine landholding size, quality and location. Well-off households tend to have level plots with black soil located near drainage lines or the village tank, whereas poor and marginal households tend to have the red soil, high gravel content plots up the hill. Second, well-off farm households most often have access to irrigation, both because of the location of their lands and because of their better access to financial resources. Third, well-off farmers can better afford agricultural inputs like fertilizers, bullocks and, indirectly, manure. Fourth, large households have more hands available for both on-farm labor and wage labor off-farm. Especially in the case of small households with few resources, on-farm labor is a serious constraint. Hiring labor is too expensive, and most of the time the household has to work off-farm to earn a steady income for themselves. Also, in case of labor-intensive investments this forms a crucial constraint. Fifth, better-off households can invest more in the agricultural production potential of their land. Sixth, better-off households tend to be more literate and have better access to extension services and innovative techniques.

Hence, whereas the better-off households tend to shift investments to the production of higher value crops, poor households have difficulties in investing anything at all in agricultural production. For these households, public investments in soil and water conservation could really benefit the productivity of their lands. However, these households in general have benefited the least because of the location of their land and their marginal role in village decision-making. Also, poor households tend to work more on other people's lands, reducing the time and effort available to invest and maintain investments on their own land. That even on poor, uphill soil improvement is possible was shown by the example of the landless laborer in Vaiju Babulgaon, who bought and converted 7 acres of extremely marginal land. However, such examples are an exception, not the rule, since they require a risk taking attitude and strategic capacity that most poor people cannot afford[11]. With over 30% of the farm households in India's semi-arid regions considered poor (Ryan and Spencer 2001), poverty, probably, poses the most crucial constraint to improve the yields of dryland crops.

5. CONCLUSION

The major watershed development investments undertaken by the government and others in India were to some extent supposed to stimulate dryland agriculture like how the green revolution had stimulated the growth of irrigated agriculture before. Although investments were relatively low, the expectation was that by investing in agricultural production potential the productivity of dryland agriculture could be greatly improved.

The results of our analysis do not show a significant effect of watershed development on the yields of dryland crops. However, these results are affected by the prolonged drought, and farmers indicate that they expect more benefits in good rainfall years. At present, investments to improve soil moisture on private lands seem most effective for households with black soil and land located downstream. However, the main beneficiaries of watershed developments are households with access to irrigation. The skewed distribution of watershed benefits has reduced the potential impact on dryland yields, as farmers with access to irrigation tend to shift towards more water-intensive crops. Supplemental irrigation is only used in case the costs of irrigation are low and the benefits of stabilizing dryland crops are high. This is only the case in Vaiju Babulgaon where irrigation takes place through open wells and dryland crops are used for dairy cows.

In general, the choice of dryland crops seems to be a negative choice. Farmers, who can afford to diversify, rather invest in more water-intensive, high-value crops like horticulture, vegetables and oilseeds instead. Only on the more marginal, infertile and remote lands do farmers grow dryland crops. These lands tend to belong to the most marginal households, who cannot afford to invest in labor, agricultural inputs or improved seeds. Even if public investments are made in soil and water conservation, these farmers often prefer to work for wages than to maintain investments on their land. If under these conditions the yields of dryland crops were to be improved, the most important intervention would probably be to address the root cause of poverty itself. Lack of access to productive means, poor health, poor education, high risk adversity, low wages and a weak negotiation position in village decision-making all constrain dryland crop productivity in an indirect way. Some watershed development projects have attempted to address these constraints, for example by starting

[11] Poor people tend to be extremely risk averse and to discount the future in favor of the present, foregoing productive investments to enhance yields in the long run (Ray 1999, Bardhan and Udry 1999).

micro credit programs and improving access to agricultural extension services and productive means[12]. In fact, in both Kanakanala and Vaiju Babulgaon, such interventions were made, but a more thorough analysis would be required to assess the impact of these interventions on poor households and the yields of their dryland crops. Raising the yields of dryland crops minimally requires that the conditions faced by poor households are specifically addressed. Exploring the possibilities of risk insurance, subsidized access to irrigation, crop-livestock linkages[13] and specific extension services for the poor are just some examples of what this might involve.

If dryland crop yields are to improve at a broader scale, interventions might be needed to change dryland crop production from a default option to a positive choice. This would not only require changes in the broader incentive structure, like market prices and household demand, it would possibly require local water demand management as well. Since, without access to irrigation (and/or alternative livelihood options) the risks of dryland production in population-dense India are simply too large, water use needs to be spread more evenly and its use managed within the limits of natural and artificial recharge. However, regulating local (ground) water use is notoriously difficult and it seems unlikely that local water demand management would become a reality soon. Hence, with unequal access to resources, to improve the productivity of dryland agriculture larger interventions are needed than merely investments in soil and water conservation . What these interventions should be remains open as further research would need to be done, but instead of a pure focus on physical potential, farmers' interviews suggest that the socio-economic constraints for dryland production need more attention as well.

[12] See for example Farrington et al. 1999 and Joshi et al. (2004).

[13] See for example R. Puskur, J.A.Bouma & C.A.Scott (2004).

Groundnut farmer, Vaiju Babulgaon watershed, October 2004.

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