Social organization and small watershed development

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An overall strategy that has been proposed for the improvement of semiarid tropical (SAT) crop production is integrated land and water management for cropland development on a watershed basis (Kampen 1980, Krantz et al 1978). Research at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has focused on small watersheds, which would usually involve the land of more than one farmer in areas with operational holdings and field sizes similar to those of southern SAT India (Tables 1 and 2).

Modeling work and economic analysis at ICRISAT have strengthened this expectation, pointing for example to watersheds of 8-16 ha as a size likely to be economical for development on Alfisols and under rainfall and economic conditions similar to those near Hyderabad during the late 1970s (Ryan et al 1980, Ryan and Pereira 1980). Small watersheds chosen as sites for experimental development in the villages Aurepalle, Shirapur, and Kanzara were close to this size range and comprised the land of 5, 12, and 14 farmers (Table 2). These circumstances mean that an understanding of conditions for group action among farmers is needed for small

Table 1. Owned land of farmers[a] sampled in 3 villages of southern semiarid tropical India, 1975-76 crop season.

	Aurepalle	Shirapur	Kanzara
Mean land area (ha)	6.0	5.0	5.5
Median (ha)	2.6	5.0	3.1
Range (ha)	0.3-38.6	0.8-14.2	0.8-28.4
SD	8.3	3.3	6.2
CV	138	66	113

[a]Landowners in ICRISAT's village level studies (Jodha et al 1977). Sample size: Aurepalle = 29, Shirapur = 30, Kanzara = 30.

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Table 2. Field size data from small watersheds selected for development in 3 villages of southern semiarid tropical India, 1978-79 crop season.

	Aurepalle	Shirapur	Kanzara
Farm owners per watershed (no.)	5	14[a]	14[a]
Av field size (ha)	3.5	1.2	1.4
Total watershed area (ha)	17.7	16.8	19.9
Fields (no.) by size (ha)			
0.1-1.0	1	7	8
1.1-2.0	1	3	2
2.1-5.0	2	2	2
5.1 and above	1	0	1

[a]In two cases in Shirapur and one in Kanzara, two members of a family hold title to portions of the same field.

watershed development.

Identification and understanding of anthropological conditions for group action have been a major research focus in ICRISAT's economics program since the latter part of 1976. Approaches have included study of the literature regarding cooperation for agricultural production, examination of particular cases from India, and a study of relevant anthropological work on group size and function (Doherty and Jodha 1979, Doherty 1980). We also analyzed on-farm experiments in watershed development, begun in 1978-79 and carried through the 1980-81 season, by staff of ICRISAT's farming systems research program and economics program in collaboration with Indian institutions. In this paper we analyze cases of cooperation involving well ownership in the same three southern Indian villages where the small watershed development projects were conducted. Some results of the on-farm experiments are also noted.

From the anthropological part of this work, we concluded that two distinct types of cooperative behavior can be discerned in human groups. Knowledge of these types of cooperative behavior can be applied along with knowledge of the relative sizes, longevity, and appropriateness of tasks for human groups under different conditions (Doherty 1980). A summary statement of the two types of cooperative behavior, as well as appropriate group size, follows:

> *Rule-based* behavior can be observed in individuals, small groups, or large groups. Predominantly passive and persisting over the long term, rule-based behavior is in principle predictable and invariant, although the rules themselves may change from time to time. Effective, long-term rules are most often generated and sanctioned by relatively large groups. *Decision-based* behavior requires management judgments and will call for different actions at different times. This behavior is situational and is effectively performed by individuals, or by small groups that cohere only for the short-term, decision-making task at hand. Such small groups may have a cross-culturally optimum size. They can cohere over the long term and make repeated, variable management decisions only if they have the strong and continually reinforced, rule-based sanctions of a large group or of an active, well-organized administration to support them. Decision-based activity may weigh the application of potentially conflicting rules or it may deal with areas where no rules apply.

We believe that, along with the results of land and water management experiments and of economic analysis, such conclusions can be important in the design and large-scale implementation of technology and programs to improve agricultural resource use in the SAT on a small watershed basis.

MULTIDISCIPLINARY RESEARCH AND THE ROLE OF ANTHROPOLOGY AT ICRISAT

Studies of how improvements to land and water management in SAT areas can be made on a watershed basis show how multidisciplinary research is conducted at ICRISAT, and how anthropological work contributes to such studies. The two studies on which details are given are 1) a special investigation focusing on unadministered, cooperative use of wells by farmers in southern SAT India, and 2) experiments in small watershed development in farmers' fields in the same area.

At the time work on small watershed development technology was initiated at ICRISAT, there was no anthropologist on staff. Scientists in the economics program and farming systems research program were agreed, however, that problems of social organization and group action could be expected in on-farm contexts because the proposed technology would be area-based rather than field-based and would involve the land, resources, and interests of more than a single farmer. It was felt that knowledge about possibilities for and limits of group action would be necessary even in a research station context, for proper design, development, and evaluation of the technology. On-farm trials were planned for an early date, and it would be necessary to have an anthropologist as a member of the on-farm team to participate in analysis of farmers' assessments of the watershed-based technology.

An anthropologist was recruited in the economics program to work primarily on problems of group action connected with watershed development.

Initially, a joint anthropological and economic analysis was made of theoretical literature and of Indian case studies of cooperative action by farmers (Doherty and Jodha 1979). This 1976-77 study was followed by a more detailed examination of anthropological literature (Doherty 1980). Agronomic tests on farmers' fields were begun during the 1978-79 agricultural season to prepare the way for field testing a modified package for small watershed development the following season. These studies were the joint work of scientists from ICRISAT and from member institutions of the Indian Council of Agricultural Research. The studies of cooperation involving wells were carried out during 1979-80.

On-farm studies are a particularly important area in which ICRISAT researchers from different disciplines and programs combine their efforts, within a common framework, to focus on solutions to problems of SAT farmers. An important context for this cooperative, multidisciplinary research at the field level has been the village level studies program (VLS) (Jodha et al 1977, Binswanger and Ryan 1980) which were initiated in 1975 by members of the economics program in cooperation with agricultural universities of Andhra Pradesh and Maharashtra States. The studies have been expanded recently with the collaboration of the agricultural universities of Gujarat and Madhya Pradesh, as well. The studies are designed to enable analyses of farming practices and problems from a wide range of baseline data from a stratified, random sample of farm and labor households in villages typical of Indian SAT sub-regions. The study villages have been envisioned from the first as areas where a wide range of on-farm experiments is possible, from evaluation of existing practices, through biological and physical observations, to the experimental testing of particular technologies such as watershed development.

The initial study of anthropological and economic material regarding group action was a cross-disciplinary effort similar to work on rainfall runoff modeling begun at ICRISAT in 1975. In each case, researchers from different disciplines pooled their insights and knowledge to suggest answers to a technological problem concerning ICRISAT as a whole. From preliminary results, different follow-up and investigations were suggested. In the group action study, it was clear that two sorts of studies would be needed. One would be on-farm experimentation, which would involve researchers from a number of disciplines and farmers in the field application and evaluation of technology designed according to hypotheses about what would be agronomically, economically, and organizationally successful.

It was clear to the anthropologist, the economists, and others concerned with the farming systems research and economics programs that additional disciplinary, focused studies would be necessary to resolve questions raised by the early group action studies. Such special purpose studies would also be needed if ambiguities likely to arise in the results of the on-farm work were to be resolved. These considerations led to the studies of indigenous cooperation around wells.

The data for the study on wells reported here were collected by an anthropologist and two assistants as part of a general data-gathering effort on a variety of problems with which ICRISAT is concerned. The data are evaluated here by a group of authors, including researchers in land and water management. The land and water management strategies proposed for SAT areas are given in Appendix 1. An anthropological evaluation of the strategies, based on the analysis in this paper, is given in Appendix 2.

SOME MEASURES FOR WATERSHED DEVELOPMENT IN THE SAT

In an agricultural sense watershed development means the conservation, improvement, and use of soil and water resources in a given drainage area for increased crop production. Development may or may not involve areas used for trees and grassland. This depends upon the demand for different products and upon the nature of the resource base. Natural resources include soils, subsurface geology, rainfall with its runoff and drainage patterns, and groundwater and surface water. Water resources may include aquifers and rivers, which may not depend wholly upon precipitation in the particular catchment. One can envision a variety of resource use and associated problems. Where rainfall intensity and surface and subsurface drainage limit crop production, improvement of land drainage should form a major portion of watershed development. Periodic drought stress often limits crop production in the SAT; in such areas, water conservation and water storage as groundwater or in surface reservoirs assume great importance.

Watershed development research at ICRISAT in Patancheru, near Hyderabad, India, is designed to identify principles that can be used to develop profitable,

intensive farming systems for areas with low and seasonally concentrated rainfall and with relatively infertile, tropical upland soils. Work has focused on improved land and water management suitable for small watersheds (3-15 ha). Broadbed-and-furrow cultivation on a slight grade has been used to improve rainfall infiltration and storage in the soil profile, while still providing surface drainage. Runoff is conveyed through grassed waterways and collected in small storage reservoirs or ponds arranged in series to recapture overflow.

This approach to watershed development and resource use has performed well in experiments at ICRISAT and elsewhere. The technique may be particularly useful in promoting intensification of cropping in some deep Vertisol areas of India where rainy season fallowing is common (Binswanger et al 1980). In some of these areas, drainage problems can prevent cropping in the rainy season. Broadbeds and furrows could alleviate the drainage problem and still allow significant amounts of soil profile moisture to be carried over into the dry season.

A 70-year simulation shows that on Alfisols under conditions such as those at ICRISAT, the optimum sizes of small watersheds are from 8 to 16 ha, if runoff is impounded and pumped to irrigate a second, postrainy season crop (Ryan et al 1980) Water use is improved by more flexible decisions on cropping pattern, planting date, and irrigation pattern in response to seasonal and market variations. On Vertisols, with better moisture storage and less runoff, the economics of ponds seem less attractive This situation becomes more pronounced the lower the rainfall and the deeper the Vertisol (Ryan et al 1980). A better understanding is needed of the potential for runoff collection and use on different soils under different rainfall regimes.

BACKGROUND TO FIELD INVESTIGATIONS IN GROUP ACTION

The suggestion that runoff collected in ponds be used for supplementary irrigation on small, upland crop watersheds raises many questions. What are the organizational, physical, and economic feasibilities of this upland crop system vs collection of runoff in tanks for gravity irrigation of paddy rice? (The common South Asian term tank refers to traditional reservoirs with earthen dams for collection of runoff. These can have catchments varying greatly in size and irrigate from 10 to 100 ha or more. What would be the returns to ponds for supplementary irrigation of upland crops, vs returns to wells? Could percolation tanks be built more profitably to recharge groundwater and improve the yield of wells? The hydrological, agronomic, and economic answers to these and other questions, as well as the formulation of the questions themselves, will be location specific

In all cases, however, one can expect questions to arise about the social organization of ownership and use of such irrigation facilities. Therefore this paper concentrates not on any particular situation in any given area, but upon the derivation of social organizational principles that can be applied along with physical, biological, and economic principles. Ponds could be desirable from other viewpoints, but one must also be able to decide on the most efficient system of ownership and management, and be able to judge whether such a system can be instituted. The type of social organization required will vary not only according to the nature of the resource but according to the desired results. It will be defined in part and limited by cross-cultural, social, and cultural elements.

Data in Table 1 are on farmer-owned land in three villages (Aurepalle, Shirapur, and Kanzara) of the southern Indian SAT. For situations in which median holdings are 2.6, 5.0, and 3.1 ha, optimum watershed sizes of 8 to 16 ha seem too large for most farmers to develop profitably on their own. Actual plots suitable for small watershed development are often much smaller than farmers' total owned areas (Table 2). This is due to diversification of holdings by soil and location as a risk avoidance mechanism, and to fragmentation of lands at inheritance. From the data in Tables 1 and 2, one could expect to encounter small watersheds owned by groups of 2-10 farmers if one were to begin a small watershed development program in areas of similar ownership pressure on agricultural land. If the farmers who own the fields on these small watersheds were to develop them in common and build collection ponds for supplementary irrigation, they would have to cooperate over the long term and make many seasonal decisions regarding water use and maintenance.

In such a situation we need to know if there are rules, particularly cross-cultural ones, for cooperation in small groups. We then need to know, based on an understanding of such rules, the potential for cooperative ownership and management of ponds on small watersheds. In two earlier papers about cooperation among farmers, a concept of matching appropriate group size and function was developed (Doherty and Jodha 1979, Doherty 1980). On the basis of a comparative ethnographic view, one could hypothesize that small groups of unadministered, independent individuals are likely to be most effective only as short-term task groups, while much larger groups are likely needed to support social mechanisms for continued, variable decision making, and for drafting and enforcing impersonal rules. Both papers also hypothesized that individual and group interests would have to be served. This would be particularly important where individual farmers are independent decision-making agents.

Based on the general hypotheses regarding group action, a specific hypothesis was advanced regarding farmers' preference for ownership and operation of ponds and similar facilities. This hypothesis stated that farmers would prefer individual ownership of small sources for supplementary irrigation (Doherty 1980).

ORGANIZATION OF THE USE OF OPEN WELLS FOR IRRIGATION

Data on ownership and management of wells were collected to provide a partial test of the hypothesis that farmers would prefer individual ownership of small sources for supplementary irrigation.

The cases to be considered are the rules for ownership and management of open wells found in the same three villages where the experiments in small watershed development are being carried out. These villages are also located in the three districts where ICRISAT village-level studies (VLS) are being conducted (Jodha et al 1977). Background on the areas in which the villages are located is given in Table 3.

Only those wells in which a VLS respondent either shares or has full ownership rights are discussed (Table 4).

Table 3. Features of village-level studies districts, semiarid tropical India (adapted from Jodha et al 1977).

	Mahbubnagar District Andhra Pradesh State Aurepalle Village	Sholapur District Maharashtra State Shirapur Village	Akola District Maharashtra State Kanzara Village
Soil types	Shallow and medium Alfisols	Deep and medium-deep Vertisols	Shallow and medium-deep Vertisols
Av annual rainfall (mm)	713 (bimodal rainfall)	691 (rains undependable and received in two distinct phases during rainy season)	817 (rainfall relatively dependable)
Cropped area irrigated (%)	14.5 (tank and well irrigation)	10.7 (largely well irrigation)	1.5 (largely well irrigation)
Important crops	Sorghum, groundnut, castor, rainy season pulses, paddy on irrigated lands	Postrainy season sorghum, pearl millet, groundnut, pulses	Sorghum, cotton, groundnut, rainy season pulses
Regions represented	Alfisol tracts of the eastern Deccan Plateau	"Scarcity zone" of Maharashtra and Karnataka on the western, central, and southern Deccan Plateau	Vidarbha region of Maharashtra and neighboring parts of Madhya Pradesh State

Table 4. Well ownership among village-level studies (VLS) respondents in semiarid tropical India, 1979-80 agricultural season.

	Aurepalle	Shirapur	Kanzara
VLS wells[a] (no.)	23	18	16
VLS wells used			
no.	17	12	11
%	74	67	69
VLS respondents with at least a share of well ownership			
no.	19	17	13
%	48	43	33
VLS respondents (no.) with an interest in more than one well	7	2	3
Av well share size among VLS owners[b] (%)	0.67	0.46	1.00
Av cumulative well ownership among VLS well owners (%)	0.81	0.49	1.23

[a]All wells for which a VLS respondent was sole or part owner during the postrainy agricultural season of 1979-80. There are 40 sample families in each village, 30 depending mainly on farming for their income, and 10 depending mainly on agricultural labor. The 30 farming families are drawn 10 each from large, medium, and small landholding groups (Jodha et al 1977). [b]Includes active and inactive wells.

The most wells are in Aurepalle where the rainfall is low, there are many good aquifers, and an extensive system of tanks and bunds has the effect of recharging groundwater. Many of the Aurepalle wells are old, having been dug several generations ago, before diesel or electric pumps were available. In Shirapur, presumably because of low and undependable rainfall, there are many wells despite extensive deep Vertisols that are highly water retentive. Kanzara has the fewest wells; rainfall is higher and relatively dependable. The shallower soils in Kanzara are underlain by rocky substrata that do not provide high yielding, shallow aquifers. Many Kanzara wells have been built since the early 1960s when diesel or electric power for pumping began to be widely available and the government began subsidizing loans for well construction and the purchase of pumps. Differences in rainfall, cropping patterns, soils, and subsurface geology likely influenced the patterns of well ownership in the three villages.

The high incidence of overall well ownership in these three villages is striking. At the time of the study, wells were the primary source of irrigation in these villages.

The average number of owners per well and the average number of active owners per well (Table 5) suggest that small groups do form themselves around these organizationally independent sources of supplementary water. Many wells have been under shared ownership for several generations: most changes in ownership seem to occur through inheritance. Pumps are also owned in common. These results seem contrary to our hypothesis regarding group ownership of small sources of irrigation.

The natural agricultural environment appears to be a key determinant of common well ownership. The most owners per active well and the most irrigating farmers per active shared well are in Shirapur, where rainfall is the least dependable. Shirapur also has the most owners per pump. Although Shirapur's deep Vertisols retain

Table 5. Shared ownership and use of wells in village-level studies (VLS) sample in semiarid tropical India, 1979-80 agricultural season.[a]

	Aurepalle	Shirapur	Kanzara
Owners (no./active well)	2.4	4.8	1.0
Active owners (no./active shared well)	2.7	4.5	0
Active VLS wells with shared ownership			
no.	12	10	0
%	71	83	0
Owners (no./active pump) in VLS sample	1.4	3.5	0.7

[a]Actual use as opposed to ownership of pumps may vary periodically because of factors such as lack of production funds on the part of some farmers, and renting out of shares by others.

moisture well, farmers still want wells and own them in common. One hypothesis consistent with the data would be that although small groups of owners form and persist around these wells, shared ownership is organizationally difficult and it may be uncommon unless alternatives are not attractive.

Water control systems and the degrees and kinds of interaction among farmers were also investigated. Water control systems minimize interaction among the owners. Farmers do not meet to consider the season as a whole and to devise ways to increase the productivity of their shared water resources. On the contrary, the systems assure that the rights of each individual operate automatically by invariant principles.

Several principles govern the shared use of wells in Aurepalle. First, each owner's share is fixed at a known fraction of the total capacity of the well. Second, owners are individually responsible for raising the water. If a farmer cannot afford the electric bill or has no bullocks to raise water, no one else is obliged to help. Third, there seems to be a de facto upper limit on irrigated area in proportion to one's share in the well. If a well owner does not own enough land within reach of the well to make full use of his share, and if he cannot purchase land near the well, he may sell his rights in the well and perhaps the land. Fourth, all owners are obliged to share proportionately during drought; all pumps must be turned on and off at the same time. Fifth, the pump size can be limited by horsepower, being installed in at least some cases according to the size of a person's well share so that no one realizes an unfair advantage when all pumps must be operated together.

The greatest portion of irrigation in Aurepalle is for paddy rice, the locally grown crop with the highest water requirement. If all farmers use water at the maximum rate and if the other limitations are observed, proportional equality can be maintained.

In Shirapur the well sharing system is based on different rules. Presumably because of the drier climate and lower yielding aquifers compared to Aurepalle, Shirapur wells are not used for paddy. Farmers assume that any irrigated crop planted in the area needs water approximately every 8 days. Rights to water are therefore reckoned in terms of days, with 8 days' rotation a common figure. A er will own 2, 3, or 8 days' rights in a given well. For one day's share, a farmer is entitled to as much water as the well will yield from sunset to sunset. No time extension is possible and a fixed rotation among the farmers is set. The practical irrigable area of a well is determined when it is built; this area is called the malha. In Shirapur as in Aurepalle, there seems to be a de facto irrigated land limitation on farmers in addition to prescribed rights to the well water itself. Well rights are inherited or sold along with malha land proportional to the number of day shares involved.

There is a greater incidence of joint ownership of pumps in Shirapur than in Aurepalle. The joint ownership system probably originated in farmers' attempts to cut their capital costs — the tendency is probably reinforced in Shirapur by the rotational pattern of well use.

VILLAGE-LEVEL EXPERIMENTS IN SMALL WATERSHED DEVELOPMENT

Beginning with the 1978-79 crop season, ICRISAT staff assisted in trials to develop small watersheds, which in 1980-81 involved cultivated areas of about 14 ha in Aurepalle, 13 ha in Shirapur, and 12 ha in Kanzara. Other data relating to these watersheds are given in Table 2. The work was done in collaboration with scientists of the All India Coordinated Research Project for Dryland Agriculture, the Andhra Pradesh Agricultural University near Hyderabad, and the Punjabrao and Mahatma Phule agricultural colleges in Maharashtra.

Recommendations implemented included the introduction of:

- graded, broad bed and furrow cultivation, and sowing;
- improved crop varieties;
- fertilizer; and
- improved, bullock-drawn tool carriers for planting and for fertilizer placement.

Catchment drainage was improved by conveying runoff along existing field boundaries and by channeling it through waterways and concrete drop structures across fields along natural drainage patterns. In one village, two owners exchanged small portions of adjacent fields to simplify cultivation on the proper grade for the 2-year duration of the experiment. In another case, grade lines were laid out across field boundaries to simplify planting.

All these developments were directed and implemented by ICRISAT research staff. The farmers agreed to the various operations and cooperated actively in the work within their field boundaries. Where work was outside their fields or cut across boundaries, as in the construction and maintenance of the drainage system, the farmers were also cooperative, but their cooperation was mainly passive.

The experiments were begun with the understanding that the farmers in each village would be subsidized for the 2 years of the experiment. The choice of crops was theirs. No charges were levied for land drainage development, nor has the retention of these developments been enforced beyond the 2-year period. ICRISAT agreed to pay all extraordinary costs for labor and bullocks, and to advance the material inputs such as seed, fertilizer, and pesticide.

After the first year, it was agreed that in subsequent years cooperating farmers would repay ICRISAT for material inputs but only if their average net profits were

double those realized on similar nonexperimental fields in the same villages.

Because the techniques were untested on farmers' fields, the financial subsidy was necessary to minimize the cooperating farmers' financial risks. ICRISAT coordination was withdrawn when the financial supports were terminated but technical advice continued on request.

No ponds were built on the watersheds in the study. In Aurepalle an existing well in the watershed was used for supplementary irrigation to facilitate growing a second crop in any year there was sufficient groundwater. In Shirapur, where rainfall is low and unreliable and soils are deep Vertisols, a pond would be an unlikely investment. Possibilities for pond construction were also limited by the short duration of the experiment and the need to guarantee that farmers' freedom of action would be minimally affected during the experiment and would be completely restored when it ended.

We can make a broad social organizational assessment of farmers' reactions to the first 3 years' activities. Where the system could handle runoff without overload, farmers generally did not object to an improved drainage system that followed field boundaries and natural features within fields. Nevertheless they showed strong interest in maintaining boundaries, protecting individual rights, and adapting improved tillage and planting to individual field patterns. Some farmers have objected to concrete drop structures within fields, but not to those on boundaries. Farmers have expressed interest in renting or purchasing bullock-drawn tool carriers and attachments. They have shown a strong aversion to shared ownership of tool carriers.

The farmers' individualism expressed in these ways confirms some predictions of our earlier studies (Doherty and Jodha 1979, Doherty 1980). Nevertheless we have seen in the same villages that stable small groups form around water sources.

CONCLUSION

The behavior of the VLS sample farmers who share rights to wells in Aurepalle and in Shirapur contradicts our hypothesis that farmers would prefer individual ownership of small sources of water for supplementary irrigation. In the face of these data, we cannot simply assign short-term functions to small groups and long-term functions to large ones. The data can be accommodated, however, if we revise our hypothesis, taking into account decision-based vs rule-based behavior, as well as the functions of small groups as opposed to large groups.

The systems of cooperation followed by farmers who share rights to wells in Aurepalle and Shirapur are clearly rule-based. The systems governing ownership and management apply in the village as a whole. Farmers who obtain access to a well need not worry about what the rules will be. Decision-based interaction, in which one person's decisions on cropping pattern or irrigation timing might influence the well-being of his neighbor's crop, is carefully excluded by customs governing shared ownership and use of wells. We suggest that such rule-based activity is suitable for small or large groups, even though the larger group ultimately must sustain and sanction it. It is functionally and organizationally opposed to decision-based activity. Decision-based activity is efficiently carried out by individuals, by short-term small coalitions, or by small or large groups under a centralized management.

Thus we revise our hypothesis to state: farmers would prefer that small sources of irrigation water, such as collection ponds on small watersheds, be individually owned, unless simple rules for distributing water could be specified in such a way that interaction and common decision-making among owners would be reduced to low or negligible levels. To the degree our findings have cross-cultural validity, we expect that it might be possible to modify the severity of these requirements in certain cultural and social contexts, but not to evade them in any case. As a supplement to the present study and its precursors, additional cross-cultural comparison of cases and circumstances should be done. Social organizational insights also need further study. Still, the revised hypothesis seems well-founded. We submit that the distinctions drawn here between rule-based and decision-based behavior, and between the functions of large and small groups, will prove to be significant in the design and assessment of agricultural technology to meet the needs of the SAT and other areas.

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Appendix 1. Land, crop, and water management improvement strategies proposed for SAT agricultural areas.

Major problem area	Specific problem	Solutions proposed
Drainage	Stagnation and waterlogging	Land shaping; planting on grade; beds and furrows where appropriate; comprehensive drainage on an integrated, small watershed basis.
	Erosion	Land and water management measures same as for stagnation and waterlogging; grassed waterways; permanent drop structures in waterways; fast, efficient crop establishment in the rainy season because crop cover is the most important erosion alleviator.
Moisture deficits	Timeliness and precision of operations	Use of improved, bullock-drawn tool carrier for faster and more efficient land preparation and seeding; use of improved seed drills and fertilizer applicators to increase water use efficiency and nutrient uptake by seedlings.
	Increase moisture storage in the soil profile	Tillage and planting on grade; broad beds and furrows where appropriate.
	Use of runoff water for crop production	Collection and use of runoff water in ponds for lifesaving or supplementary irrigation or both. Construction of larger reservoirs (tanks) for gravity irrigation.
	Use of groundwater	Examine potential for wells of different types in the SAT, and for improving groundwater availability.

Appendix 2. Anthropological evaluation of proposals for improved agricultural land, crop, and water management in the SAT.

Improvement	Group action involved	Probabilities of success
Land shaping	Decision-based or rule-based agreement for an essentially one-time, short-term activity.	High likelihood of organizational success for individuals or small groups. Possible high cost relative to returns realized over a long term may require government subsidy or organization or both to initiate such activity.
Planting on grade with or without broad beds and furrows as appropriate	Decision-based activity. Adoption requires farmers to balance levels of labor available and other factors against costs in time and effort to set up and maintain a specific land management pattern which may require time and patience to realize full results.	Best confined to within-field patterns for individual farmers at first. Minor field boundary reorganization problems may emerge. If use of the new techniques is profitable enough, individuals or small groups can be expected to adjust these on their own.
Watershed-based drainage improvement with or without grassed waterways	Only rule-based cooperation would be required if government were to install the system and protect it legally thereafter.	High probability of success if imposed and then backed up by rules. Preference for systems using existing field boundaries as runoff removal areas to the greatest extent practicable.
Grassed waterways	Rule-based acquiescence at least is required because waterways serve the watershed as a whole.	Where the waterways could fully control runoff, little particular objection to the definition of waterways within fields was experienced in on-farm experiments. These experiments, however, revealed severe difficulties with establishment of the grass itself and this in turn made control of heavy runoff difficult in some cases. Solution of these technological problems is probably more important than group action if leaving waterways in grass is to prove more profitable to farmers than plowing and planting the waterway along with the rest of the field.

Improvement	Group action involved	Probabilities of success
Improved, bullock-drawn tool carriers and attachments	Complex system involving many variable decisions.	High probability of success for individual ownership whether for own use or for hire. Little or no probability of success for joint ownership by small groups of independent farmers.
Ponds for runoff collection and use	Decision-based or rule-based activity by small groups of farmers or by individuals depending on watershed size, landholding patterns, and cropping patterns.	Very low probability of unsupervised group success, given size of group and type of activity involved, if water to be used in a flexible manner on a changing mix of dryland crops. Indications are that ponds could be used by individuals where landholding size permits, or that they could be used by groups in a less flexible manner.
Tanks for runoff collection and gravity irrigation	Rule-based activity most likely	Government would likely be interested in tanks as government supervision would likely realize a relatively high rate of return. More research needs to be done on types of area-based drainage and runoff collection, and on the types of institutions required to support them for pond and for tank irrigation.
Open wells	Both decision-based and rule-based use are possible.	Studies in VLS villages show that small groups of farmers who own shares in the same well can cooperate on the basis of simple, invariant rules. More research needs to be done on wells as an indigenous focus of group action, which could perhaps be improved for greater SAT crop production given the right institutional structure and increased research and development on groundwater recharge and use.