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Opportunities For Expanding Water Harvesting In Sub-Saharan Africa:
The Case Of The *Teras* Of Kassala

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OPPORTUNITIES FOR EXPANDING WATER HARVESTING IN SUB-SAHARAN AFRICA: THE CASE OF THE *TERAS* OF KASSALA

Johan A. Van Dijk & Mohamed Hassan Ahmed

Recently settled pastoralists in the Kassala Border Area of East Sudan are combining different livelihood activities, including different run-off farming techniques, to fulfil their subsistence needs. The *teras*[1] technique of water harvesting is widespread and offers good opportunities for run-off manipulation and moisture storage. Despite relatively high labour requirements and low grain yields, the *terus* are critically important in strategies of holding dispersal and hence of risk. In this paper, we discuss the value and extent of *teras* close to Kassala. Its small scale, private management and adaptive capacity make it a technology replicable in other areas of Sudan and in Sub-Saharan Africa (SSA). In order to achieve this, rural programmes must tap the proven rich source of indigenous knowledge more than is presently the case.

Renewed Attention for the *Teras*

The *teras* technique for water harvesting is based on the principle of increasing soil moisture for plant growth by reserving part of the landholding for the capture and conveyance of rainwater to the arable land. The system aims at moisture conservation with storage under saturation or field capacity conditions. Nutrient conservation and erosion control usually are positive secondary effects. The *teras* technique is widespread in semi-arid central Sudan. The distribution is largely between the 200 and 500mm isohyets and coincides with the clays of the plain, one of the world's largest contiguous vertisol areas. The *teras* origins are still obscure but recent technical, historical, and especially linguistic evidence point to Funj influence and Nubian roots. The technique might have evolved out of the Nile irrigation basins, first to low-walled basins for in-situ moisture conservation, and later to *terus* which are open on the upslope side to let in run-off. This evolution would date rudimentary forms of the technique back to the Funj Kingdom, which rules between 1504-1820.

Recently, the remnants of prehistoric water harvesting artifacts have also been discovered in Nubian land along the Nile (Mohamed Saleh, personal communication, February 1992[2]) and have been identified on aerial photographs. Any direct link between this system which

1. Singular teras, plural terus

2. Current research is conducted in the programme "Project for Systematic Archaeological Survey of the Mahas Region" led by Dr. Ali Osman Mohamed Saleh, Director of the Department of Archaeology, University of Khartoum.

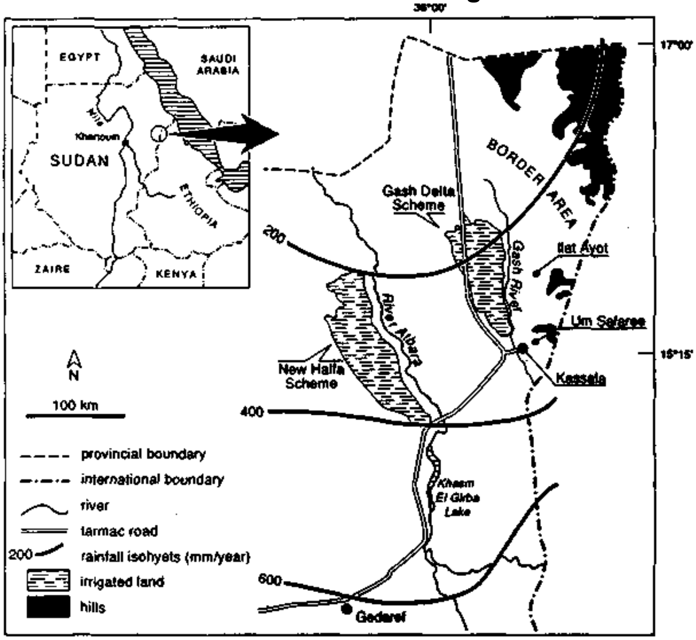
uses rock catchments and the *teras* must still be investigated. In the area around Kassala, however, early agricultural contacts with the Nile cultures have been confirmed by archaeological evidence (Fattovich, 1990). Finally, more recent contributions to *teras* development come from the West African pilgrims to Mecca who started to settle in Kassala from the end of the 19th century. Their descendants now engage in the expansion of *teras* land and the successful commercialisation of the *teras* farming system on the plain west of Kassala town.

Past scientific interest in the *teras* has been short-lived, chiefly because the earliest studies were published around the 1960s when all eyes were on Sudan's large-scale irrigation efforts. The technology is described in Tothill (1954), Barbour (1961), Randell (1963), Lebon (1965), and De Vadja (1966). With notable exceptions (see Abu Sin 1970, El Amin Ahmed Babiker 1980, Ibrahim 1988), more recent publications on run-off farming in Sudan rarely mention the *teras*. We discuss the *teras* in some detail but limit our scope to the Kassala Border Area of Sudan's Eastern State, where they are largely for subsistence of recently settled pastoralist households.

The Border Area Environment

The area east of the Gash river and tarmac road in the Kassala Province is called the Border Area. It covers 8,600km², at some 500-600 metres above sea level. The average annual rainfall (1938-1990) is 286mm, though in eight years out of ten it is only 215mm. The plain is cut by some 30 large seasonal water courses, *khors*, running east-west to southeast-northwest. All discharge into the seasonal Gash river and its inland delta. *Khors* with a

Figure 1: Kassala Border area with research villages



large catchment have well-defined beds. There are numerous smaller and discontinuous *khors*, where run-off repeatedly spreads in alluvial flats and concentrates where the gradients steepen. This typical pattern is the driving force behind different run-off farming systems in the area including the *teras*. The Border Area environment is highly dynamic: drainage lines regularly change course and processes of erosion and sedimentation rapidly succeed each other in one and the same area. It lies in the belt of *Acacia* tortilis desert scrub with active sand dunes in the extreme north and *Acacia mellifera* thornland in the south.

The Border Area traditionally is one of pastoralist peoples. Beja tribes of Hadendoa and Beni Amer are the main groups of whom increasing numbers have settled since the 1950s. Early 1940-revised topographic maps show some four settlements in the area whereas now some 30 villages exist each with an average 2,000 population. Just outside the Border Area around Kassala, the Rashyda pastoralists are settled in increasing numbers, mainly because of the mid-1970s drought, official government recognition since 1977 of their settlements, and the supply of water and services (El Hassan, 1987). The 1983 census mentions a Kassala Rural Council population of 71,500, giving a population density of about 8.3 per km^2. Density is higher in Beni Amer land around Kassala and generally lower densities in the more remote and harsh Hadendoa territory in the north. The annual population growth rate (1956-1983, provincial level) is 3.8%, predominantly related to refugee settlement (MFEP/UNDP 1990).

Livelihoods in the Border Area are best described as sedentary and transhumant agro-pastoralism. Income from seasonal migration and off-farm employment significantly contributes to household subsistence. The main migration destinations are the government-managed irrigation schemes of New Halfa and the Gash Delta. Daily migration trips are made to Kassala, and off-farm activities include local labour and trade, fuelwood and water collection, and the production of charcoal. Pastoralism is in crisis. The Eritrean war made trekking routes into the highlands insecure. The Gedaref large-scale mechanised farming schemes block traditional routes to the southern wet-season pastures. More or less captured in the Border Area, herds were decimated in the recent 1984/1985 drought years. The area's natural resources are degrading, with the potential for grazing and forestry overused, but the agricultural potential still underused (DHV/IES 1988).

Local Farming Systems

Cultivation in the Border area is still mainly for household subsistence needs. Sorghum (dura, *Sorghum bicolor*) is the dominant crop with some ten local known varieties. Millet (*Pennisetum typhoides*) is sometimes grown on lighter sandy soils. Next to sorghum with yields in the range of 250-850kg/ha, stalks used for fodder and in building yield an additional 2000 kg/ha. Other crops grown on part of the holding include okra (*Hibiscus esculentus*), karkadeh (H. *sabdariffa*), watermelon, sometimes lubia (*Dolichos lablab*) or sesame. Okra and watermelon increasingly are also grown as cash-crops.

At present, land preparation is manual in most of the Border Area. Camel or oxen-drawn ploughs were used until a decade ago. Since the early 1970s, tractors hired from contractors have become more important in the Kassala perimeter. Sowing is after the first favourable rains or spates, normally in July. Cropping densities are variable (row spacings of 60-100cm and usually more fixed plant spacings of “step-length” 80cm) and with high populations (5-10 seeds/hole). Thinning is not a regular practice but gap filling is, especially under wild-flooding systems. Quick-maturing varieties are used when such resowing is late in the season. Weeding in two or three rounds is by hoe but one round is usually skipped when lands are tractor-ploughed. Weed competition on scarce soil moisture can be severe and is occasionally reason to shift to adjacent land, or abandon the area completely.

There is no conscious manure application, but *khor* spates do wash animal droppings onto the arable lands. Crop and weed residues further improve the soil nutrient status. Activities of land preparation and increasingly also of harvest, transport and storage are carried out by hired labourers. Traditional farmer workgroups of mutual assistance, *nafir*, seem to be declining in importance, especially near Kassala town. The growing commercialisation of production is given as the chief reason. Strict rules for gender relations in the Beja society make farming almost entirely a man’s job. Only young Beni Amer girls sometimes assist on the field during harvest time.

Border Area agriculture performs better if additional run-off water is made available for cultivation. We distinguish here between indigenous techniques of water harvesting and wild-flooding. The first is defined as the collection and concentration of surface run-off for plant production before it reaches (in our case) seasonal streams. In wild-flooding the run-off is not collected or manipulated: unprepared land is sown directly after wetting by spate flow. The systems however easily mix and frequently no clear boundaries can be drawn between the two. Local indigenous water harvesting variants include run-off manipulation by (i) u-shaped earth bunds, or *teras* (harvesting rain or floodwater) and (ii) brushwood panels, or *libish* (harvesting floodwater). The *teras* discussed below is the most common water harvesting technique in the area.

The brushwood panels, or *libish*, are built of bundled branches cut from Acacia spp., *Prosopis juliflora* and increasingly from low valued *Calatropis procera*. Branches are wattled and secured into the soil with hooked pools. Panels are 20-30cm (up to 75cm) high and are of variable lengths. When filled with debris captured from the run-off, the panels act as permeable barriers. The technique is used on level land for run-off collection (when built on downslope sections of the holding) or run-off spreading (on upslope sections). To a lesser extent, panels are also used for gully erosion control. The structures generally require seasonal rebuilding since they are prone to destruction for firewood use.

Other run-off engineering techniques include the rectangular earth basin, or *hafir*, and protection dikes. The *hafir* is constructed by excavation and addition of a retaining wall. An earth dam in the *khor*, sometimes also a conveyance channel, diverts water to fill the reservoir for domestic use and the watering of cattle. Basins used to be hand-dug but since the 1950s, government programmes were started to mechanise construction and maintenance. There are 27 *hafirs* in the Border Area all with effective storage under 10,000 m3, which is less than a third of the design capacity. *Hafirs* suffer from rapid siltation. In some areas, seasonal floodwaters menace the village built-up areas and earth dikes are built for protection.

Households follow a strategy of spreading their holdings over these distinct zones while using different run-off farming techniques. In this way, risk of crop failure in any one zone, and under any one technique, is reduced. The average number of holdings per household in the area is 2.15. The strategy which may involve daily travel times of over two hours is labour-intensive. A shortage of labour therefore is a main bottleneck to the full exploitation of all holdings. This is significant for the *teras*, which has by far the highest construction and maintenance demands. Key-variables on labour-sensitive farming practices (see Table 1) illustrate that the resulting pattern of labour allocation, however, is fairly uniform over different techniques, despite the varying returns these techniques provide.

Table 1: Selected farming practices and sorghum grain yields by run-off farming system (Border Area Holdings, wet year 1988/89 and dry year 1983/84)

	Teras		Brushwood Panels		Wild Flooding	
	Wet Year	Dry Year	Wet Year	Dry Year	Wet Year	Dry Year
No. of cultivated holdings	62	64	19	20	69	60
% prepared holdings[1]	74	80	88	95	Na	Na
% of weeded holdings[2]	80	73	89	85	77	71
% of area cultivated	67	66	68	57	65	69
Average Sorghum yield (kg/ha)	514	257	471	343	664	343

(1) Teras: bund maintenance and/or repair, catchment cleaning; Brushwood: panel raising and/or repair; Wild flooding: no preparation required.
(2) Weeding twice or more.

These yields are low when compared with the major farming systems in the region. Sorghum returns under controlled spate irrigation in the Gash Delta in the same wet and dry years are respectively 1190 and 620kg/ha. Rainfed mechanised farming around Gedaref under a more favourable rainfall regime (see Figure 1) produces an average 1000 and 470 kg/ha in wet and dry years (MANR 1987, 1991). These production figures of the Border Area water harvesting techniques are roughly comparable with data from similar systems in Sub-Saharan Africa: bunds in Somalia yield a comparable 415 kg/ha, and the small, semi-circular '*demi-Lunes*' of Niger may yield 250 to 600kg/ha; but in Kenya, bunds may produce up to 1300kg/ha, and in Burkina Faso, stone bunds (some used in combination with planting pits) yield around 1000kg/ha (Reij et al, 1988; Reij,1990; Critchley et al, 1992).

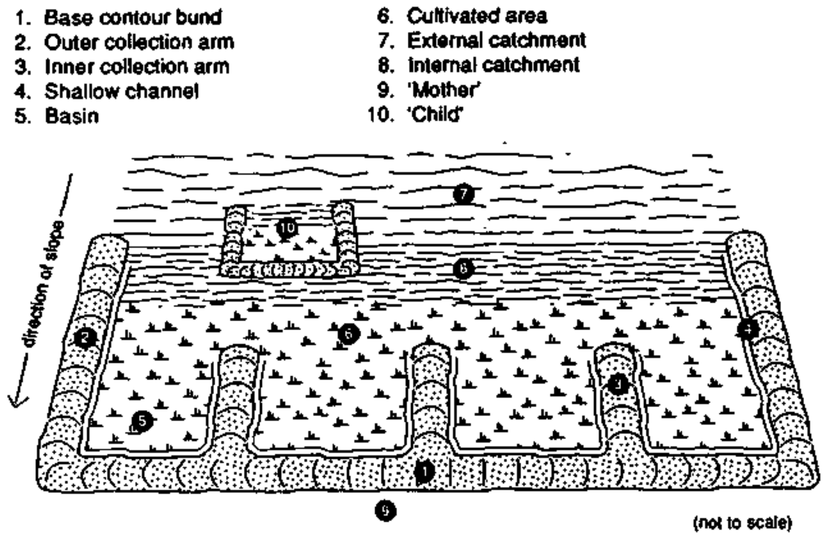
The *Teras* System

The *teras* system includes two main elements: (i) the cultivated land which is bunded on three sides, and (ii) a rainwater collection area or "catchment" located at the open side upslope of the cultivated land. The basic system as used in a wide region of the Eastern State is discussed first before elaborating on more complex local variations.

Characteristic of the *teras* system is the base bund built approximately on the terrain contour (see Figure 2). It impounds captured rainwater and allows it to infiltrate into the soil. The outer collection arms partly have the same function, but also act as conveyance structure. The arms at a right angle to the base direct the run-off to the cultivated land. Shorter inner arms divide the land into smaller basins to effectively impound minor supplies of run-off. In certain areas (and especially in the concave-armed variants discussed below) run-off circulation is manipulated by changing the length of some of the inner arms. Individual basins in this way are given a thorough wetting before the spill is routed to neighbouring compartments. The same principle applies for the "*child*" *teras* sometimes built in the catchment of the main structure ("mother").

The dual objective is to benefit from small run-off volumes generated by light early rains, and to reduce flow velocities to less erosive magnitudes when rains swell later in the season. The construction of *teras* bunds leaves shallow channels in the field. The excavation material is usually taken from the inside face of the structure. The resulting ditch supports the conveyance and circulation of run-off. Excess water normally is drained along the tips of the outer arms, which are reinforced for this purpose with virtually any material locally available: brushwood, small stones, worn out tires. In case of severe flooding of *teras* land, the contour bund is deliberately breached to avert the more devastating event of an uncontrolled burst.

Figure 2: Typical element of the *teras* structure for water harvesting



Bund height is usually 0.5m, with bases 2m wide. The dimensions vary with slope and amount of run-off expected in the area. Base bund lengths are between 50-300m (recorded maximum lengths up to 700m), with arms usually 20-100m (up to 200m). The ratios of base: arm dimensions are not fixed, but base bunds with lengths under 100m seem to have more constant ratios, i.e. 1: 0.6-0.7 which makes the *teras* relatively deep. Base bunds over 100 m generally go with shallow systems with ratios around 1: 0.3. Sizes of cultivated land accordingly usually range between 0.2-3 ha.

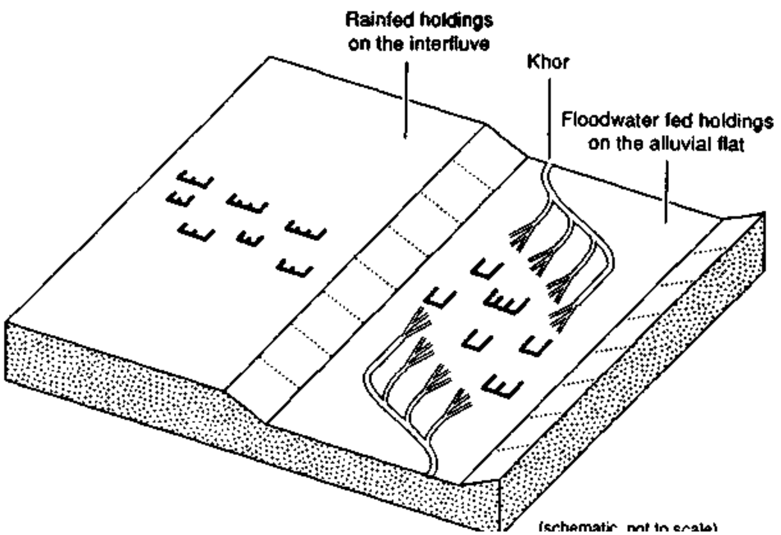
The rainwater catchment is external to the cultivated land. However, any land not under crops adds an additional internal catchment area. The entire catchment area is to a large extent defined by the configuration of *terus* in a given farming zone. A regular spacing is common with base bunds aligned on the contour and a slightly staggered pattern in the direction of the slope. When there are no upstream land users, run-off collection can be from an unbounded area. Inside a given configuration, the bounded external collection area usually has a catchment to cultivated area (ca:c) ratio between 3:1 and 2:1, up to ratios of 4:1. Internal catchments vary in size according to the area cultivated, which is frequently not more than 50% of the entire holding.

Airphoto-mosaics compiled of material dated 1963-1967 show an area under *teras* (including occasional brushwood techniques and patches under wild-flooding) of an estimated 20,000-40,000 ha, which is 2-5% of the Kassala Border Area[3].

Variations and Functions of Structures

The complex drainage pattern leads to a true kaleidoscope of *teras* designs in the Border Area which can best be described in terms of shape (rectangular/irregular), dimension (shallow/deep) and basin characteristics (single/multiple basin). Available 1986 airphotos of the research area show that base and outer collection arms usually make rectangular bunded areas, but *terus* also appear in irregular semi-circular hoops. The design seems related to micro-topography, characteristics of water supply and environmental dynamics.

Figure 3: Teras water harvesting in the Border Area landscape



3. The 1:250,000 scale of the mosaics does not permit detailed observations, while more recent photos do not cover the entire area

Stable environments with an evenly distributed supply of run-off (rainfed or surface waters) over level land, show more rectangular *terus*. These are usually shallow (base contour bund longer than any collection arm) and of the multiple-basin type, but single rectangular basins do occur. Where drainage lines, run-off volumes, erosion and sedimentation processes are more subject to change, irregular hoops occur. Structures usually are deep (arms longer than base bund) and more often of the single-basin type. A similar association of physical parameters and *teras* shape is observed in other dynamic zones of the Eastern State, for example on the east bank of the Atbara river. Another characteristic *teras* is a variation of the rectangular basin which has one concave outer collection arm, for we have different explanations. Some *teras* users model the arm to catch the maximum sheetflow run-off with a minimum of breach hazard. Others refer to it as spillway to drain excess water.

The Water Spreading Research Kassala (WARK) surveys shed more light on how the *terus* are used in farming systems. Only 22% of all holdings are located on the interfluves and are entirely rainwater dependent. The remaining *teras* holdings are on the alluvial flats and benefit from run-off naturally spreading upstream of the farming area. Their catchments are smaller, *teras* configurations are adjusted to drainage lines and are not strictly aligned and staggered. Slopes are generally under 1%. The recorded average ca:c ratio (total catchments including all internal and external collection areas, averages 1983/84 and 1988/89) for rainfed structures is 2.3:1. For surface water supplied holdings the figure is 2:1. Table 2 lists more characteristics for cultivated *teras* holdings.

Table 2: Characteristics of *teras* holdings, (Border Area, cultivated holdings, averages over 1988/89 and 1983/84).

Characteristics	**Ha**
Average size holding	3.0
Average size cultivated land	1.6
Average size total catchment, of which:	7.3
internal catchment	2.4
internal and external catchment	4.9

Note: external catchments may be (partially) located outside the holding.

Construction, Maintenance and Repair

Teras bunds are built of the local alluvial and colluvial material. Bunds invariably are positioned on sight. Detailed terrain knowledge allows farmers to orientate new structures in such way that run-off yields are maximised. Building sites on the cracking Badobe soils, gravels or hard pans are avoided. Diversions are built of earth with reinforcements of the same material used in brushwood panels. In the past, structures were larger and complete trunks of the doum palm, *Hyphaene thebaica*, were used, the felling of which is now controlled by law. All techniques using woody material are declining in importance with the dwindling plant cover: while earth dams are up to 1-1.5m high with a 3m to 4m base, brushwood diversions do not reach heights over 0.5m.

Traditional construction of earth bunds and diversions is by hand, using simple tools like hoe, spade, axe, and baskets. In the dryer northern part, bunds frequently are also naturally raised by wind action. For this purpose, an initial 20-30cm low ridge is built and brushwood is placed on the windward side to capture additional sand. Strengthening with clayey material and compaction is required after one year to complete the bund. Remarkably, the earth scoop, or *wasuq*, commonly used in irrigated gardens around Kassala town is never used for bund raising or other *teras* land preparation.

Labour requirements for *teras* building mainly vary with soil characteristics and period of construction (with highest perso nhours for dry season building on heavy clays). Maintenance makes substantial demands according to type of damage, gully erosion occurrence, and degree of weed infestation. *Teras* building is usually in different phases, which allows the necessary adjustments by trial and error. An average *teras* would need 60-110 person hours/ha preparation (Table 3). The building of brushwood panels by comparison needs an estimated 12 person hours/ha, while wild-flooding requires no preparation. All subsequent labour needs for general farming practices are largely equal under the three systems.

Table 3: Characteristics of *teras* holdings, (Border Area, cultivated holdings, averages over 1988/89 and 1983/84).

Labour requirement	Person hours per hectare
Investment (building)	36-95
Seasonal maintenance:	
repair	48-71
catchment cleaning	12-36

Tractors mounted with a disc-ploughs are increasingly used for bund construction and repair. This operation takes about 2.5 hours/ha and includes the ploughing of the land. The scale of mechanised operation decreases with increasing distance from town. In 1988 for example, no tractor service was available in the remote village of Ilat Ayot while in Um Safaree close to Kassala town 57% of the *teras* holdings were mechanically ploughed or maintained.

Teras maintenance and repair is the responsibility of the individual farmer, cooperative action is mainly restricted to the communal diversions in water courses. If operating collectively, Beni Amer more frequently participate in *nafir* workgroups than Hadendoa, but the latter organize around patrileneally linked groups of households, or *dawa*. All tasks of construction, repair, and maintenance are exclusively executed by the male farmers. Light seasonal maintenance is a recognised means to safeguard land titles in disputed domains. Maintenance activities start in May or June, shortly before the onset of the rainy season. Heavy earth work is postponed if possible until the first rains have softened the soil. Protection works are applied on bund tips which act as spillway and also on other parts of the bund. Former breaches, low bund sections, and gullies are covered or filled with brushwood, stalks and crop residues, sand bags or small stones. Scrubs emerging on the bund are sometimes preserved. Stability gain apparently outweighs the hazard of yield loss to birds, which menace is behind fierce plant eradicating campaigns by farmers in the area. If necessary, bunds are raised, arms remodelled and catchments cleared of vegetation.

Sedimentation is a serious threat to *teras* cultivators. While some windblown sand is easily cleared from the land, run-off deposits are more difficult to deal with. In one Ilat Ayot *teras*, the rate was estimated at some 2cm/yr. Bunds need regular heightening to keep pace with the rise of cultivated land. Breaches in such situations result in considerable damage. The inherent natural land levelling process inside the *teras* also reduces irrigation efficiencies. Only the most laborious task of all can solve this problem: certain sections, or even entire *terus*, are rebuilt on upstream land to improve the run-off catch. In the Clay Plains west of Kassala, such relocation also occurs when weed infestation and soil exhaustion are considered to reduce yields too much. Perceived and reported disadvantages of the *teras* are heavy weed infestation, sedimentation, gully erosion when bunds breach, and uneven wetting of the land.

Teras-Specific Farming Practices

Within the calendar set by seasonal rainfall and spates, the *teras* offers good opportunities for run-off manipulation and moisture storage. Crop selection is adjusted accordingly. Grain preferences mainly relate to taste. Characteristics of yield, stalk and stover, and resistance to pests are secondary considerations. When different sorghum varieties are used, quick-maturing dura (mainly 70-days Feterita) is grown upstream in the holding, or in the *teras* "child". Near the base bund, longer season varieties of 85-days Wad Feraj, 110-days Hagartai or 150-days Aklamoy are grown where there is higher soil moisture. Cropping densities are usually raised when run-off yields in the *teras* are high. Sorghum monocultures are less common in *teras* holdings (45% against 63% and 71% of holdings under brushwood and wild-flooding respectively, season 1988/89) and mixes with vegetables or millet are favoured. The crops other than grains are commonly grown in the shallow channel which normally receives a good wetting. Vegetables were included on 20% of the 1988 teras holdings against 13% of those under wild-flooding and 11% under brushwood.

Social and Economic Aspects of Teras

The Sudan government holds *de jure* titles of unregistered land, but cultivators enjoy de facto customary usufructary rights. The village domain is the scale of organisation where the sheikh in a committee of wise men supervises land allocation. Land and the different run-off farming techniques are open to all, but leading residents have preferential access to upstream lands. This is more common on alluvial flats under wild-flooding or brushwood panels, than on the *teras*-dominated interfluves. Occasional mention of land competition was exclusively with reference to the flats, not to interfluves.

The share of *teras* land in village farming domains is at present some 35% and 40% in Ilat Ayot and Um Safaree respectively. Airphotos of 1963/1967, 1978, and 1986 show little change in area with the notable exception of a decline between mid-1960 and 1978 for Um

Safaree located closest to Kassala. Between 1978-1986, new *terus* were increasingly built on the alluvial flats rather than the interfluves. Local people explain these trends from decreasing annual rainfall. There is however no full support from meteorological data: the *teras* decline in Um Safaree was in the relatively wet years of the two decade period. Other factors of importance for the developments in the area are: (i) the opening of the New Halfa irrigation scheme (1964) for which the government started seasonal labour recruitment in Border Area villages, (ii) tractor introduction in the Border Area (early 1970s) which changed comparative advantages of different farming zones and scales of operation, (iii) the rapid growth of Kassala town (4-6% annually in last decades) and its service apparatus including transport links with the rural Border Area, generating a considerable flow of rural-urban migration. The effect of all these developments was felt more strongly in areas close to Kassala. The consequences for Border Area farming systems, and for the *teras* in particular, are still under study.

If all income and (animal) wealth was stated in monetary terms for comparison, a modest 10% of the gross household wealth of settled Beja is derived from local farming. Livestock related activities (commercial herding, trade, marketing livestock produce, and animal wealth proper) and migration (of various duration) add on an average 77% and 12% to household wealth. Within the share of local farming, lands under water harvesting measures (brushwood panels and *teras*) contributes a high 80%. About a quarter of the Border Area households finds an additional source of grain in sharecropping in the Gash Delta. If this non-local farming is practised, it forms an average 70% of the total household grain stock (all data are averages over wet and dry years 1983/84 and 1988/89).

A modest commercial orientation in vegetable growing is developing under traditional techniques in the Border Area. The market-oriented *terus* of the Clay Plains west of Kassala producing watermelons for Port Sudan urban markets 600km away, clearly have demonstrated the potential of this focus.

Policy Recommendations

Government concern with indigenous run-off farming techniques in the Border Area since 1982 has focused on earth diversion dams. Substantial improvements have been achieved in this by introducing protection measures using brushwood and other material. Diversion dams furthermore have been remodelled into spreader dams which are located on the arable land and no longer in *khor* beds. Earth dams also have been aligned on the contour. Finally, derived techniques of low contour earth embankments have been tested in pilot schemes since 1987. The results of all these efforts have remained below expectation (Cosijn and Van Dijk, 1989; Van Dijk, 1991). More recently the merits of the indigenous *teras* have been ‘rediscovered’.

The advantages of the *teras* when compared with earth dams lie in their small scale and private management. But what is more important, the *teras* is entirely farmer-managed. Former pastoralists who only started settling in the area some four decades ago have taken it up, have adjusted it to their needs, and a growing number are using it successfully. *Teras* water harvesting is now firmly embedded in a wide array of subsistence activities which have become vital after the change to a more settled livelihood. Under the extreme conditions of the Border Area, the *teras* proved a valuable tool in survival strategies of spreading holdings and risk. Increased subsistence security however does require relatively higher overall maintenance costs and lower overall yields. The recent *teras* developments show that farming households are willing to pay this price.

There is a potential for expanding *teras* water harvesting in the Border Area and similar regions in Sudan and dryland Africa. The comparative advantages are only fully realised when farmers are allowed to retain their capacity to analyse, choose, and experiment in land and water use (Chambers, 1991). Although the main challenge lies with the farmers themselves, some support from the government and other institutions is essential. Support is needed at two different levels at least: the first is the level of the household, the second is at the level of the holding.

Water harvesting in marginal dryland areas rarely is a stand-alone activity. Farmers analyse, choose, and experiment with different household subsistence activities. When one of these is believed temporarily inaccessible for whatever reason, others are turned to and act as a safety net. Livelihoods then are very much a performance with sequential adjustments through time to unpredictable conditions (Richards, 1991). This is regularly overlooked in donor and government programmes. Technical packages are offered in which at crucial moments labour bottlenecks are being faced because farmers also prove to be herders, seasonal migrants, traders, charcoal makers, woodcutters or water fetchers.

Support should be given to the full exploitation of all subsistence opportunities and not focus on only one component. Public support at this level should upgrade infrastructure and facilitate access to vital resources of arable land: both in the Border Area and in government schemes, of local pasture and corridors to seasonal grazing grounds, of labour where required, of capital. Sometimes access to tractors should be considered, as it is a genuine and growing smallholder practice in the Border Area. Finally, access to information and markets is important. In short, an enabling environment should be created where settled pastoralists can organise their livelihoods themselves.

At the holding level, the same concept of performance is applicable and again farmer analysis, choice, and experiment should receive full support. We briefly recall the indigenous experiments by arranging them in seven groups:

- controlling dynamic environmental conditions (brushwood spreader dams, anti-erosion panels, weeding ridges);
- optimising *teras* layout (size, shape, dimensions, bund height, adjusting bund trajectories);
- earth bund protection (reinforcements, deliberate breaching, cofferdams for repair work);
- testing building materials (brushwood, earth, wind-blown sand);
- testing alternative farming zones (interfluves, alluvial flats);

- testing crops and varieties (grains, vegetables, quick maturing types); and,
- testing building modes (manual, wind-blown, draught-animals, mechanized).

In several experiments like *teras* building, bund protection and repair, the central concept is a phased approach following seasonal or environmental characteristics.

These experiments are best sustained by public bodies through facilitating the access to tools and materials. Farmer training in simple methods to determine the contour by hose-level (see Chleq and Dupriez, 1988) can raise irrigation efficiencies in *terus*. Protection and repair can be improved by supplying brushwood or other vegetative material for cover. Vetiver grass, *Vetiveria spp*., is promising in this respect (Greenfield 1989) and has recently been made available in Kassala. Access to stocks of improved seed and tractor operations are other options. Especially concerning the latter, however, great care should be taken that governments or supporting NGOs do not become mere project executors. They should provide the framework for local people to develop sustainable and productive agricultural systems.

The settled Beja pastoralists in the Border Area are learning water harvesting techniques, which have almost certainly originated from a wide and distant area. In its present-day distribution, the *teras* technique has been refined and adapted by ups with longer sedentary tradition than the Beja. Learning from seeing proved a key to successful adoption and merits further support. Public institutions could promote such contacts by bringing farmers into contact with *teras*-using colleagues.

The measures discussed so far place the various institutions of donor organisations and national government in the role of facilitator. We finally add to this a clear field for further research. Biological and agronomic techniques useful in marginal areas of high temperatures, desiccating winds, and low rainfall are urgently needed for improving systems of water harvesting. Their applications in vegetative bund protection, in measures to combat soil exhaustion, and in weed management usually are not only of lower costs than mechanical techniques, but can also be made available to farmers who canmore easily add them to their long list of ongoing experiments.

Notes

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The Kassala Department of Soil Conservation, Land Use and Water Programming (SCLUWP) residing under the Ministry of Agriculture and Natural Resources is the principal coordinator of "water spreading" projects as were co-financed by the Netherlands Directorate General for Development Cooperation (DGIS). Research carried out in the context of these projects provided the first insights into the merits of indigenous techniques of water harvesting widely practised in the area. Investigations continued in the Water Spreading Research Kassala (WARK) programme of the Sudanese National Council for Research with funds from the Ford Foundation. Present research of the Department further highlights indigenous techniques in a programme financed by the Netherlands Foundation for the Advancement of Tropical Research WOTRO with supervision of the Institute of Environmental Studies and the Faculty of Environmental Sciences of the University of Khartoum and University of Amsterdam respectively.

The information presented in this paper at the level of holdings is based on 20% random samples of households in the villages of Um Safaree and Ilat Ayot studied in the WARK programme. A second major source are aerial photographs and mosaics of 1963-1967, 1978 and 1986 of the Khartoum Survey Department. A holding is defined as the discrete area to which a land user is entitled for cultivation. Holding and area under command of run-off farming artifacts do not necessarily coincide. The bunds of the *teras* usually cover and command only part of the holding. Other definitions concerning run-off farming we use here mainly follow those of two World Bank Technical Papers on the subject (Reij et al, 1988; Critchley et al, 1992).

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