

POLICY ALTERNATIVES FOR LIVESTOCK DEVELOPMENT IN MONGOLIA (PALD)

A Research and Training Project



Research Report No. 6

Preliminary Assessment of the Potential of Rainwater Harvesting for Fodder Production

Adrian Cullis*
with Dr. S. Jigjidsuren
and Tserenpiljee Bujantogtoh**

* Intermediate Technology Development Group, Rugby, UK

** Research Institute of Animal Husbandry, Ulaanbaatar, Mongolia

April 1993

TABLE OF CONTENTS

GLOSSARY OF MONGOLIAN TERMS	ii
SUMMARY OF MAIN CONCLUSIONS AND RECOMMENDATIONS	iii
1. INTRODUCTION	1
2. THE MONGOLIAN PASTORAL ECONOMY	2
The Mongolian environment	2
Mongolian collectives	3
Constraints to production	4
Crisis years	5
Herder and policy responses to production constraints	7
State Emergency Fodder Fund	9
3. IMPLICATIONS OF POLICY REFORM	12
Needs assessment	12
4. FODDER OPTIONS FOR THE GOBI REGION	15
fodder options	15
5. RAINWATER HARVESTING	17
Overview of water harvesting systems	17
Early technical and social assessments	22
Lessons from Australia	23
6. A PLANNING FRAMEWORK FOR WATER HARVESTING IN THE GOBI	25
Coordinating body to develop a national fodder plan	25
Specialist water harvesting unit	26
Timetable of activities	26
REFERENCES	29
APPENDICES	
1. MONTHLY RAINFALL DATA FOR THREE <u>SUMS</u> : BULRAN, GURVAN SAIKHAN AND TSOGT-TSETSY	30
2. <u>SHAGAA</u> : AN OPTION FOR PARTICIPATORY RURAL APPRAISAL	31
3. INDIGENOUS FODDER CONSERVATION TECHNIQUES	32
4. ADDITIONAL TECHNICAL DETAIL OF EIGHT WATER HARVESTING TECHNIQUES	33
5. WATERPONDING BANKS: DESIGN, LAYOUT AND CONSTRUCTION	48
6. CONSTRUCTION OF A RUN-OFF PLOT	49

GLOSSARY OF MONGOLIAN TERMS

<u>aimag</u>	province
<u>horshoo</u>	voluntary cooperative
<u>ganga</u>	deeply incised channel
<u>ger</u>	mobile hut
<u>gol</u>	river
<u>hunde</u>	valley
<u>jalga</u>	larger wadi
<u>negdel</u>	former agricultural cooperative
<u>shagaa</u>	traditional floor game
<u>sude, shuda</u>	small wadi
<u>sum</u>	administrative district
<u>suur</u>	herder's base camp in the former <u>negdels</u>
<u>torim</u>	fresh water
<u>Tugrigs</u>	national currency
<u>otor</u>	rapid herd movements for grazing
<u>owse</u>	hay
<u>zooda</u>	hand-made livestock concentrate
<u>khotail</u>	traditional herding/grazing unit composed of several households

SUMMARY OF MAIN CONCLUSIONS AND RECOMMENDATIONS

This study is a preliminary investigation of the feasibility of rainwater harvesting for fodder production in Mongolia, especially in the Gobi ecological zone.

The main conclusions are as follows:

- Traditional livestock production plays a crucial role in the national economy and provides employment for almost 40 percent of Mongolia's population of 2 million. There is no indication that the industrial sector is expanding at an adequate rate to absorb displaced herders and so extensive herding will continue to play a central role in the national economy.
- Mongolian herders face a harsh and unpredictable climate, including summer drought and extremely cold winters. Standing fodder provides an estimate 97 percent of livestock nutritional requirements, and pastures in the Gobi are of a high quality which enable animals to achieve good growth rates in years of adequate rainfall. When, as is often the case, summer rainfall is low (mean annual rainfall is below 150 mm), livestock weight gains in the Gobi are modest.
- Sharp fluctuations in livestock body weight is a feature of Mongolian extensive livestock production. The critical period for most herders is in late winter/early spring. In particularly harsh winters, when standing fodder is buried in deep standing snow, weight losses rise dramatically and animals starve. Livestock losses this century peaked in the winter of 1944-45, when an estimated 30-35 percent of the national herd was lost. Losses vary spatially and some sums have recorded livestock losses above 40 percent.
- Herders have refined and adapted herd management strategies including breeding programmes, grazing strategies, management of winter pastures, the construction of winter shelters and small-scale indigenous fodder conservation. Planners have supported herders through innovative water resource, winter shelter, fodder security schemes and provision of additional labour during critical periods.
- Since the inception of a national fodder security fund, livestock mortality rates have been substantially reduced.
- Recent policy reforms have substantially increased the role of the private sector and reduced the responsibility and power of government. These reforms have not been worked through with herders and there is a danger of alienating herders from the state. The reform process in the livestock sector is, to a large extent, dependent on a substantial increase in the market price of live animals and livestock products. Without these price increases, herders will be unable to support cost-recovery schemes. There is already a very real danger that fodder prices

will spiral beyond the purchasing power of herders in the Gobi and herders are probably more at risk than in any year since the 1960s.

- Sustained, improved livestock production under Mongolia's harsh climate is possible only if the state is prepared to play a lead role. In the arid Gobi some form of fodder subsidy needs to be maintained if herder communities are to be safeguarded. A possible example is New Zealand, a free-market economy with a comparable livestock to human population ratio to Mongolia, where large amounts of fodder are supplied to snow-bound livestock in severe winters. Costs are shared between the state and farmers.
- There are increasing questions about the long-term sustainability of large hay-making units in the north and eastern regions and there is pressing need to explore alternative fodder sources to imported hay. These could usefully include expanding grazing reserves, transfer of local irrigation schemes from crop to fodder production, up-grading local 'key-resource' pastures and water harvesting for local fodder production.
- In arid areas, seasonal rainfall run-off can be used to increase water availability through 'flooding' pastures and hence improve yield and reliability of fodder production. However, with mean rainfall in the Gobi less than 150 mm the development of sustainable and viable water harvesting systems represents a major challenge.

Based on these conclusions the team recommends that:

- Planners should, whilst continuing with economic reforms, be encouraged to monitor carefully the full cost of the reforms to the state and make necessary adjustments. Indicators in the livestock sector could include, amongst others, winter mortality rates (by ecological region) and disease and production levels (both for home consumptions and sale).
- Planners need opportunities to travel more widely outside Mongolia, in order to familiarise themselves with the full range of subsidies which support farmer/herder communities in other free-market economies world-wide (for example New Zealand, but also in Europe and North America), in order that national livestock producers are not disadvantaged by the removal of essential services or excessive cost recovery.
- The Ministry of Agriculture should be encouraged to co-ordinate the development of a national fodder plan which identifies fodder deficit areas, regional priorities, constraints and skills and lay the foundation for livestock production levels to be maintained and improved.
- As part of this plan, but not dependent upon it, the Ministry of Agriculture should co-ordinate the formation of a specialist rainwater harvesting unit to investigate rainwater options for

improved fodder production in the steppe and Gobi zones.

- Adequate resources need to be allocated to the rainwater harvesting unit in order that research work can be carried out in a range of different sites in both the steppe and Gobi zones and that the research teams are able to undertake a detailed literature review, make selected visits to other countries (for example Australia) and thereby familiarise themselves first-hand with the practical difficulties and opportunities associated with water harvesting, and develop an innovative programme of water harvesting trials.
- The rainwater harvesting unit should include a small staff of experienced field workers, who are willing to spend extended periods of time in the field and able to engage herder communities in meaningful dialogue and refine water harvesting systems to specific end-uses. The field team should be given every encouragement to learn through action and not concern themselves unduly with making mistakes (this often being the best way to learn).
- The unit should, at an appropriate time, address policy issues and explore with policy makers a range of incentives which would encourage the widespread uptake of appropriate and proven water harvesting technologies.

1. INTRODUCTION

Seasonal fodder shortage is a key constraint on livestock production in Mongolia and some argue that it is one of the reasons for the stagnation of livestock productivity since the 1960s. Certainly there is widespread agreement that existing fodder constraints need to be reduced if sustained improvements in animal husbandry are to be achieved. This study, carried out by the Intermediate Technology Development Group (IT) with the PALD project, is a pre-feasibility study of rainwater harvesting potential, as an option for improved local fodder production.

Fieldwork in Mongolia took place during September and early October 1993, and lasted a total of 3 weeks. During this time a visit to the Gobi confirmed local opinion that access to supplementary fodder is a priority concern for herders. Unlike herders in the steppe and forest steppe zones to the north, herders in the Gobi are almost entirely dependent on imported conserved fodder, to supplement standing forage. Visits were made to two aimags (provinces): Dundgovi and Omnogovi, which currently import 17,000 and 22,000 tonnes of winter feed, respectively (1990 figures). As such, in a the table of aimag fodder importation, they rank fourth and first (of 18 aimags).

On the advice of senior administrators in the Supreme Council of Agricultural Cooperatives, discussions were held with herders, company/horshoo (voluntary cooperatives) and administrators in three sums (districts): Gurvan Saikhan in Dundgovi and Tsogt-tsetsy and Bulran in Omnogovi. A brief visit was also made to irrigation schemes in Han Hongor sum, to assess the potential for conversion of the schemes to fodder production. The research team stayed in the sum centres, which enabled easy access to horshoo staff and administrators, with whom visits were made to herding families and sites of water harvesting potential.

The Gobi formed a focus for the visit and as such the material presented in this report has a strong regional flavour.

2. THE MONGOLIAN PASTORAL ECONOMY

The Mongolian environment

Mongolia essentially comprises three broad ecological zones: forest steppe and mountains to the north and north-west (27 percent), the vast eastern and central steppe (31 percent), and the Gobi desert to the south (42 percent). The climate is sharply continental with annual temperatures ranging from 45C to -40C in places. Mean summer temperatures in the Gobi are 20 to 25C, with a maximum of over 40C. Mean winter temperatures fall to -20C, with a minimum of below -40C.

Rainfall is mono-modal, with 70-80 percent falling in convectional storms in the summer months of June, July and August. The peak is particularly pronounced in the Gobi, as most rainfall occurs in July and early August. Rainfall is variable and erratic. Mean annual rainfall for three sum centres: Gurvan Saikhan in Dundgovi and Bulran and Tsogt-tsetsy in Omnogovi were 103 mm, 118 mm and 123 mm, from 1980 to the present. Monthly rainfall data for these sum centres are presented in Appendix 1.

Discussion with meteorologists and herders confirms how temporal and spatial factors impinge on pasture growth. It appears, for example, that the effective rainfall occurs in early summer, resulting in good pasture growth. Characteristically, pastures improve with late-summer rains in August and September, when the worst of the summer heat is over. Rainfall is, however, locationally specific and some areas remain dry throughout the summer season. This being the case, herders not only have a relatively short period in which to fatten livestock in preparation for the rigors of winter, but must also move herds to the best available pasture.

There are an estimated 125 million hectares of natural pasture in Mongolia. Pasture yields vary with altitude, location and year, but as a rule decrease in productivity from north to south. Pastures in the Gobi are of a higher quality than the northern steppes, with higher levels of digestible protein, which enable herders to achieve good livestock growth rates in years of adequate rainfall. When, as is often the case, summer rainfall is both low and erratic, livestock live weight gains in the Gobi are more modest.

Annual pasture production fluctuates widely around a mean of 200 kg/ha: in good years production may increase by as much as 500 percent, whilst in drought years it may fall to less than 20 percent. Pasture production data for Gurvan Saikhan, Bulran and Tsogt-tsetsy, are given in table 1.

Of the 125 million hectares of pasture land, researchers on the PALD team have calculated that 64 percent has adequate access to livestock drinking water (surface water, wells and boreholes) and can therefore be effectively utilised by smallstock (see PALD Working Paper No. 3). In the three sums visited, access varied from a high of 82 percent in Gurvan Saikhan, to a low of under 60 percent in Bulran. In all three sums it is evident that considerable investment in water resource development has maintained and increased herder access to pasture. In Gurvan Saikhan sums, for example, there are 200 improved water points. These include: 80 hand-pumps, 90

animal-powered pumps and 30 boreholes.

Table 1. Pasture yields (100 kg/ha) in three Gobi sums

	Long term mean	Maximum yield for 1993
Gurvan		
Saikhan	2.1	2.0
Bulran	2.2	1.9
Tsogt-tsetsy	1.8	1.6

Source: Hydrometeorological Research Institute

Mongolian collectives

Between collectivisation in the late 1950s and decollectivisation in 1992, the Mongolian rural economy was characterised by a complex mix of private and collective production and marketing activities. Rural households were members of either state farms or collectives (negdel). In the Gobi, unlike the more fertile regions in the north where some cropping is possible, negdel had an almost entirely livestock production and marketing function. The land area of each negdel coincided with sum or district boundaries, so no land fell outside this organisational structure.

Among other tasks the sum was responsible for education, health and veterinary care, whilst the negdel co-ordinated transport for nomadic moves, additional labour at peak times (snow clearance of winter pastures), construction of stockades, and provision of animal feed, fodder and mineral supplements.

Traditional, extensive livestock production plays a crucial role in the national economy and provides employment for almost 40 percent of Mongolia's population of 2 million. The national herd is approximately 25 million animals, of five main species: horses, cattle (including yak), camels, sheep and goats. The southern Gobi region is dominated by camels, horses and smallstock. Live animals, meat, skins, cashmere and animal hair are important exports and made up more than 40 percent of foreign exchange earnings in 1985 (Swift 1991).

Herding plays an important employment function in the Gobi, as in the rest of Mongolia, and in Gurvan Saikhan and Tsogt-tsetsy almost 50 percent of families are directly involved in herding. In contrast, however, only 36 percent of families in Bulran sum are herders. (Each of these sumen has 500 - 600 families, and a total of 2,00 to 2,300 inhabitants). Under the negdel structure, herders were allowed to maintain private livestock, numbering around 75 animals in Gobi (fewer in the steppe and forest steppe zones).

The Mongolian economy has historically been managed by national, 5 year plans. Under the appropriate ministry, plans were translated into annual targets and attainment targets set for each sum. Sum leaders would then

work through the negdel structure to apportion these targets to the various production brigades, which would then be handed-on to individual households or suur. If individual suur failed to meet their allocated annual production target, the shortfall had to be made up from their private herds or possibly through negotiation with a neighbouring household. In contrast, once production targets had been attained production from private animals could be disposed of freely. Herders received a monthly salary from their negdel. The 1990 livestock production targets for Gurvan Saikhan sum were: more than 400 tonnes of meat, 4000 sheep skins, 7.5 tonnes cashmere and 40 tonnes wool.

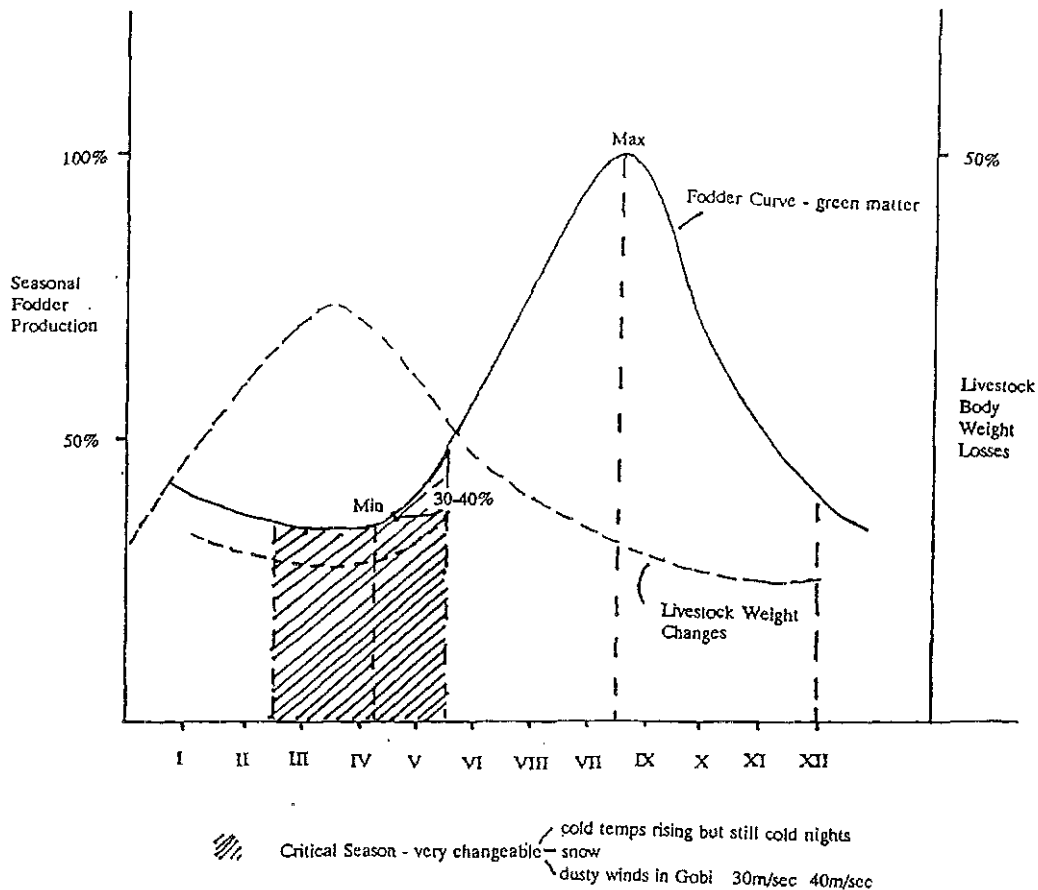
Constraints to production

As a result of the ecological factors outlined above, Mongolian herders face a harsh and unpredictable climate, including summer drought and extremely cold winters. Throughout the yearly cycle, standing fodder provides an estimated 97 percent of livestock nutritional requirements. Deep falls of snow (more than 10 cm) are particularly troublesome and feared by herders, as smallstock are no longer able to scrape away the snow to reach the grass beneath. At such times, animals are dependent on tall grasses and shrubs. Similarly, the delayed onset of summer rains, resulting in late pasture regeneration, extends the time period when animals must survive on low quality fodder.

Perhaps not surprisingly, therefore, sharp fluctuations in livestock body weight is a feature of the Mongolian extensive livestock production. The critical period for most herders is in late winter/early spring. As can be seen in figure 1, livestock body weight losses of 30 percent are not uncommon. In particularly harsh years, when standing fodder is buried in deep standing snow, weight losses may rise dramatically and animals starve. Breeding females on low quality fodder are particularly vulnerable to pregnancy toxemia.

Figure 1.

Livestock body weight fluctuations
as a function of seasonal pasture availability.



NB: Calving period co-incides with critical season

Crisis years

Livestock losses this century appear to have peaked in the winter of 1944-45, when an estimated 30-35 percent of the national herd was lost. Particularly harsh winters are, however, also recorded in 1967-68, with a 25 percent reduction in the livestock population and 1976-77, when 10 percent of the national herd was lost. A chronology of livestock losses is shown in table 2. In addition to the cash value of the livestock, fertility rates amongst surviving females is characteristically depressed and hence livestock production is affected for several years following. The time required to return to former production rates can be substantially

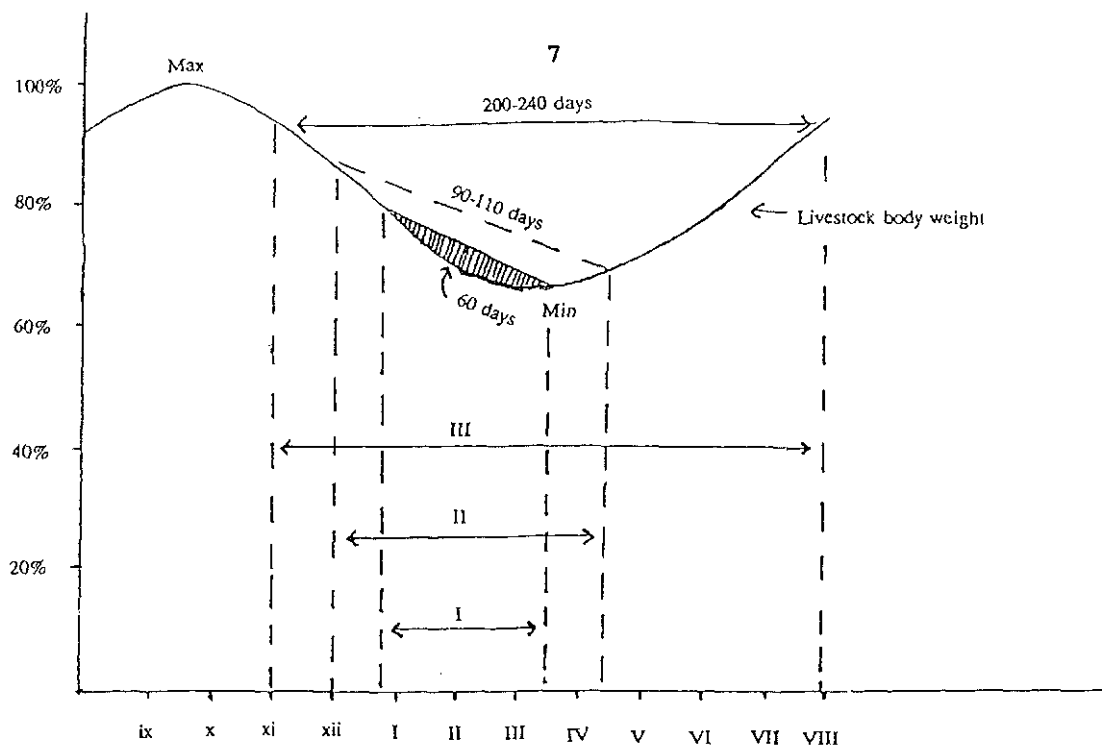
extended when crisis years are followed by subsequent poor summers and harsh winters.

Table 2. Chronology of Adult Livestock Losses: 1939 onwards

1939-59	mean annual losses ca. 1.5 million animals
1944-45	5-6 million animals
1959-70	mean annual losses ca. 1.75 million animals
1967-68	4 million animals
1970-90	mean annual losses ca. 1 million
1976-77	2 million animals
1986-87	800,000 animals

It is perhaps worth noting that there is frequently a spatial dimension to crisis years, as invariably some districts are more adversely affected than others. It is known, for example, that in the winter of 1976-77 negdel in the Gobi recorded livestock mortality rates at and above 40 percent, which is substantially higher than the national average. Evidence from research carried out in sub-Saharan Africa would suggest that richer households, with more labour, suffer fewer livestock losses than neighbouring poorer households (Toulmin 1983). It may be the case, therefore, that during the crisis years in Mongolia, not only are some sums more adversely affected than others, but that in the worst hit sum, poorer households suffer significantly higher livestock losses than richer ones.

Discussions with one herding group (khotail) in Bulran sum, resulted in the ranking of household livestock losses since 1981/82. These are recorded graphically in figure 2. The ranking exercise itself, was carried out using the knucklebones of smallstock, which are used in a traditional floor game known as shagaa (see Appendix 2). As part of this exercise, the group speculated that livestock losses for the forthcoming winter would be five times higher than in average years. In addition to the deep falls of snow, which are anticipated, it appears that the group are concerned that unlike in winters past, subsidised fodder will be less widely available.



Key:

I: 60-90 days, supplementary fodder essential

II: 90-110 days 'half-hungry' days, supplementary fodder not essential but useful

III: 200-220 some supplementary feeding useful in harsh winters

Figure 2. Need for supplementary feeding during critical period in Gobi

Herder and policy responses to production constraints

Faced with harsh winters and dry summers, herders in the Gobi have adapted and refined their herd management strategies over centuries, to enable them to survive in extremely difficult conditions. These include:

- Mongolian native breeds are adapted to cold climates and are able to conserve body heat efficiently. They are also able to maintain condition on poor quality winter grass and compensate with rapid growth weight gains in the summer.
- Herding strategies, through the summer, compensate for weight loss during the winter and seek to ensure that livestock lay down adequate fat reserves for winter. One strategy is known locally as *otor*: 'to go a long way from home (in early summer) looking for good pasture to fatten animals'.
- In early autumn, herders limit the distance moved by animals in order that they rest and consolidate body reserves. Herders also begin to overnight their animals on clear, open ground which conditions them to low temperatures ready for winter.

- Winter pastures are carefully managed in order to safeguard sheltered, south-facing pastures for extremely severe weather conditions, which are frequently experienced in the late winter/early spring. Similarly, judicious use is made of high quality resource patches (these are often small areas where run-off water concentrates and better grasses establish), for pregnant and lactating females and youngstock.

- Herders build winter shelters for animals from local materials. Young animals are also sheltered in a small ger (mobile felt covered hut/tent), which gives good protection against blizzards and low temperatures.

- Customary migration crosses administrative boundaries during periods of extreme weather (blizzards and deep-standing snow).

- Small-scale indigenous fodder conservation production helps maintain livestock body weight throughout the winter. Techniques include owse (hay), zooda (hand prepared concentrate) and use of stomach contents of slaughtered animals. (Techniques are described, together with laboratory analysis of zooda, in Appendix 3).

In order to stabilise and increase extensive livestock production, Mongolian planners have experimented with a range of interventions. Developments include a range of innovative approaches to service delivery to a mobile, livestock keeping community. These include the following:

- Water resource development through boreholes or hand-pumps and open wells has expanded the area of available pasture to herders. Herders in the Gobi report that increasing the number of water points has increased options for winter grazing.

- Improved, wooden roofed winter shelters are an increasingly common sight throughout the Gobi. Again, these are well received by herders as they afford good shelter for flocks and herds against driving winds and blizzards.

- A State Emergency Fodder Fund was launched in the 1960s and has provided large amounts of fodder to herders at subsidised prices. This has resulted in lower livestock mortality rates (see more detail below).

- Additional labour from sum centres has been allocated to livestock production brigades, during periods of deep snow to help clear pastures and to transport fodder.

- A national weather forecasting service, transmitted by radio, has supplemented herders' considerable skills and knowledge in this area. Herders are assisted to make more informed decisions regarding herding movements during winter.

- The placement of animal health assistants at the brigade level has substantially improved herders access to veterinary care and modern drugs.

State Emergency Fodder Fund

Household fodder constraints vary across ecological zones. Herders living in the mountainous regions, for example, face longer periods of deep snow than herders in the Gobi, where prevailing winds sweep pastures clean. Herders in the mountains are, however, able to produce good quality fodder for their livestock in winter and are therefore less dependent on access to

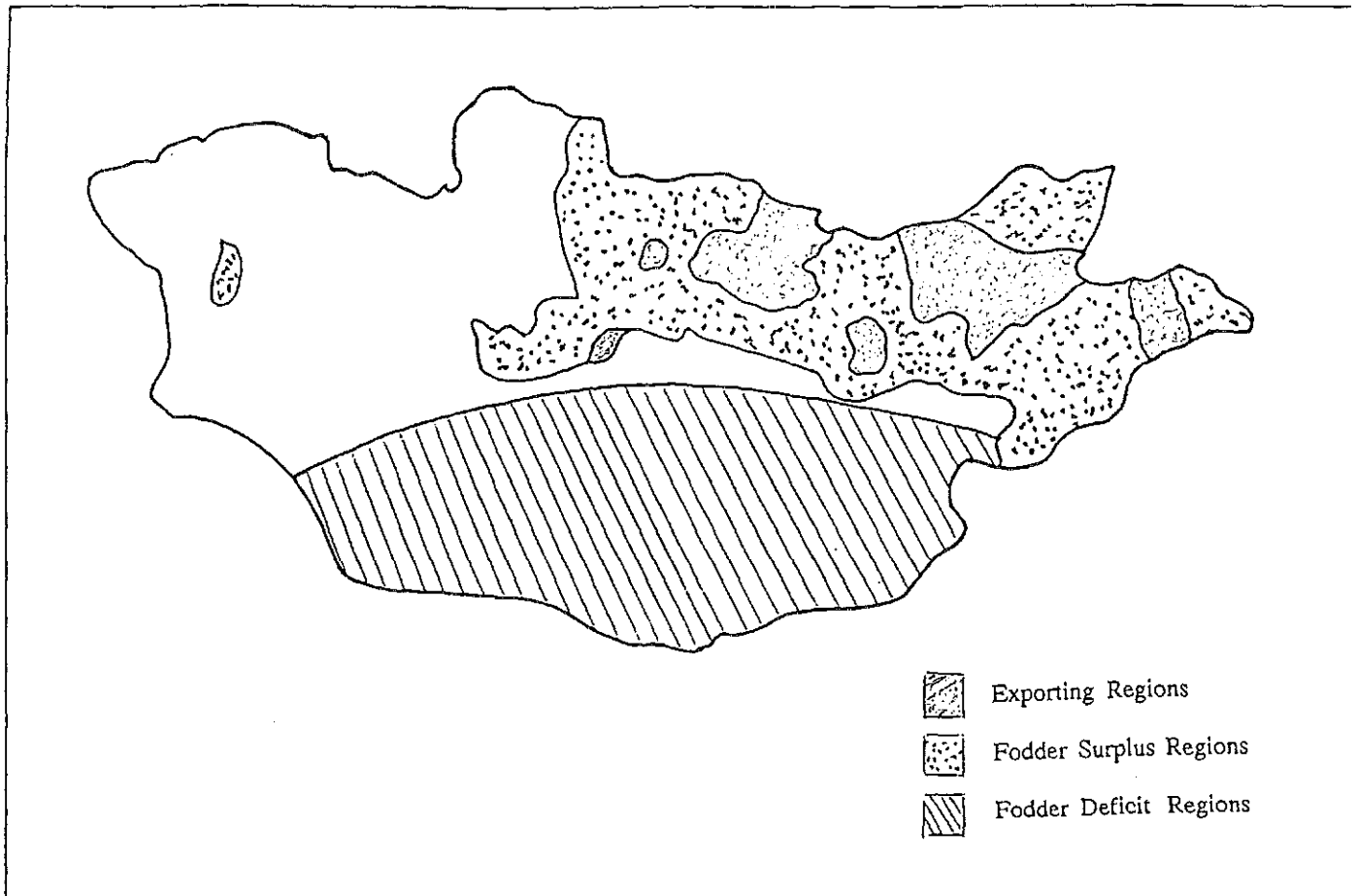


Figure 3. Hay surplus and deficit regions of Mongolia

standing forage. In contrast, herders in the Gobi are more vulnerable to deep falls of snow as, due to reduced rainfall, they are unable to prepare adequate amounts of fodder. Figure 3 shows fodder surplus and deficit zones.

Recognising this constraint, the state authorities established the State Emergency Fodder Fund in the late 1960s, in order that livestock feed could be transported from feed surplus areas of the north and east, to the south. By the 1990s, some 25 state farms and 140 small-scale units specialising in fodder production had been established. The combined annual production of

hay, straw and mixed fodder was above 1.2 million tonnes in 1990.

Perhaps not surprisingly, administrators and herders in the Gobi are enthusiastic advocates of SEFF and able to provide considerable documentary support for its rationale. For example, since the inception of SEFF, livestock mortality rates have been substantially reduced. The SEFF has a strategic importance in enhancing production levels and household income. Herders confirm that livestock losses are contained by guaranteed access to subsidised fodder, during critical periods and crisis years.

An administrator in Tsogt-tsetsy sum, illustrated the value of the SEFF in an oral report of the winter of 1991. It appears that through this winter, 70 percent of the pasture was desiccated and destroyed by blizzards. Herders alerted administrators and the SEFF was mobilised to provide an additional 600 tonnes of hay and 500 tonnes of mixed feed. As a result, livestock losses were contained to below 3,000 animals.

Fodder imports for the three sums are given in table 3. There has been a wide variation in the use made of the SEFF, with some sums importing large amounts of fodder whilst others have made limited use of the service. More dramatically, perhaps, is sum preparedness for the approaching winter at the time of fieldwork. At Tsogt-tsetsy sum, for example, no provision had been made for herders. In contrast, at Bulran sum, the team learned that fodder will not be available to private herders. If, as some suggest, herders utilise anything from two to ten tonnes of hay and two to four tonnes of mixed feed through the winter, private herders in the Gobi face an acute fodder shortfall this year.

Table 3. Sample sums: fodder imports (tonnes)

	1990	Preparations for 1992
Gurvan Saikhan:		
Hay	749.9	520
Winter feed	296.9	400
Bulran:		
Hay	436.3	Budget for ca 150
Winter feed	25.1	No preparation
Tsogt-tsetsy:		
Hay	101.4	No preparation
Winter feed	-	

SEFF is, however, not without its critics. A report commissioned by the Government of Mongolia to prepare an investment proposal for the Asian Development Bank, for example, drew attention to a range of problems. These are listed below. In view of these criticisms, it was perhaps not surprising that the consultancy report strongly advocated a programme of reform. Reform measures are also encouraged by PALD, which suggests that

"fodder supplies are a key element of privatisation ... and should be privatised as a priority during 1992" (PALD Working Paper No 3, p 22). PALD goes on to suggest that an urgent decision needs to be made regarding the private ownership or leasing of agricultural (though not hay-making) land, which currently is used for fodder production.

Problems and weaknesses of SEFF

- Herders use it each year, but have difficulty obtaining adequate quantities in harsh years.
- It is extremely expensive to operate.
- At times unnecessary freight charges are paid when fodder is available nearer to the crisis zone.
- The fund contributes to the concentration of animals around urban centres.
- It is a disincentive for herders to conserve their own hay or commercial enterprises producing hay for sale.

(Coffey MPW Pty Ltd, 1992)

- The team would also add that fodder quality is an issue. At Gurvan Saikhan, recently imported hay was clearly mixed bales of one, two and three year old grasses. As such the nutritional value of the hay was very low.

Whether guided by these reports or simply in the mounting desperation which is fuelling a headlong rush to the free-market, SEFF is being radically re-organised along the following lines:

Changes in SEFF in 1992

- The budget has been reduced enabling purchase of only 543,000 fodder units compared with 1 million units in 1991 (1 unit is equivalent to 40 percent of a sheep's daily requirement).
- Collection points/depots were cut from 41 to 3 or 4.
- Transport budget was reduced to cover cost to centres only.

Following the introduction of these changes, hay prices from state farms have risen dramatically from around 150 Tugrigns/tonne to between 1200-1600 Tugrigns/tonne. Administrators in the Gobi speculated that hay prices this year will peak at between 4000-6000 Tugrigns/tonne in the critical February/March period. Clearly herders will have difficulty adjusting to these substantial price increases.

3. IMPLICATIONS OF POLICY REFORM

Since the late 1980s, economic reforms have substantially increased the role of the private sector and reduced the responsibility and power of government. Limits on private animals in the Gobi, for example, were increased from 75 to 100 animals and then lifted altogether. Similarly, new forms of livestock leasing were introduced, so that negdel-owned livestock were leased to private herders. During 1992, negdels were formally disbanded and livestock and other assets distributed between herders and members of each sum, through a share-issue. At this point, herders were presented with a choice, between remaining within a new company forming a horshoo (voluntary cooperative), or establishing themselves as individual private herders.

The field-trip to the Gobi included a visit to Tsogt-tsetsy sum, where herders voted to privatise all herds. Tsogt-tsetsy was the first sum in Mongolia to achieve this status and it was therefore interesting to note that herders and administrators expressed anxiety and confusion with regard to maintaining services to the herding community. It appears, for example, that administrators are encountering considerable resistance to proposed increases in cash charges levied on herds watered at boreholes. Furthermore, it remains unclear how diesel-powered boreholes and animal-powered pumps will be maintained and repaired, in the longer-term.

Needs assessment

In the context of its mission, the team felt a need to explore more thoroughly local priority concerns and needs. Whilst not the only factor which determines project design, an understanding of local needs can usefully inform decision-making and resource allocation. Articulated local priorities are recorded, without any attempt to rank, in table 4.

Despite the real danger of reading too much into a simple list of this kind, it is interesting to note that a high degree of comparability exists, both between administrators and herders and across the sum. The provision of livestock drinking water was frequently mentioned first by administrators and herders. It appears that in addition to maintenance and cost sharing, the increased cost of diesel has exacerbated problems.

Neither it seems does switching to animal-powered pumps offer a satisfactory solution, as these were imported from Hungary. Whilst most of these pumps appear to be functioning well, long-term maintenance is a potential headache as Mongolia has not developed a local manufacturing capacity and spare-parts will become increasingly difficult to obtain. If water-pumps break down and remain unrepaired, herders will inevitably concentrate their livestock around existing pumps and increase the danger of overgrazing.

Concern was also expressed about changes in livestock marketing structures. Under the former command economy, state procurement orders were the main mechanism of livestock marketing and despite the limitations, high rates of offtake were achieved. Since liberalisation, an Agricultural Commodities Board with a staff of brokers has been

Table 4. Local priority needs recorded in the Gobi

Respondents	Priorities
Gurvan Saikhan sum	
Administrators:	
-	water: maintenance of boreholes and pumps
-	livestock: marketing of live animals and products
-	trade: access to basic commodities at reasonable prices
-	fodder: access at reasonable prices
-	rural electrification: in <u>sum</u> centre
Herders:	
-	water: as above and need for new supplies
-	livestock: as above
-	fodder: as above
Tsogt-tsetsy sum	
Administrators:	
-	water: as above and cost recovery at boreholes
-	livestock: shelter construction programme
-	fodder: as above
-	household income level: problems of marketing and increased prices of commodities
-	service provision: arts
Herders:	
-	livestock: marketing
-	fodder: as above
Bulran sum	
Administrators:	
-	water: as above
-	irrigation: regeneration of schemes
Herders:	
-	livestock: marketing
-	fodder: as above

instituted and every encouragement given for the 'market to set the price'. The Commodities Board has yet to develop efficient marketing channels, and herders point to stocks of skins, wool and hair which await collection. Similarly, they express frustration that marketing fattened animals has been made more difficult. One herder said that he had more than 80 fat sheep ready for slaughter, but no buyer.

Other concerns, including phasing out subsidies, the privatisation of winter shelters, the current arbitrary charging for nomadic moves (on tractors/lorries), and escalating fodder prices, also gave cause for concern. Mongolian herders face a bewildering array of policy changes, over which they have little control. The reform process in the livestock sector is, to a large extent, dependent on a substantial increase in the market price of live animals and livestock products in the Gobi. Without these price increases, herders will be unable to participate in cost-recovery schemes. There is already a very real danger that fodder prices will spiral beyond the purchasing power of herders in the Gobi and livestock are probably more at risk than in any year since the 1960s.

4. FODDER OPTIONS FOR THE GOBI REGION

Despite the brief nature of the visit to the Gobi, the team was left in no doubt that access to adequate quantities of fodder is a priority concern to administrators and herders alike. The team believe that continued access to fodder is a key element of privatisation, for without adequate winter feed livestock losses may again reach pre-1960s levels. For this reason, the team are of the opinion that there is an urgent need to look at the full range of fodder options for herders in the Gobi.

Fodder options

A possible model for Mongolia as far as fodder is concerned comes from New Zealand. New Zealand, a free-market economy with a comparable livestock to human population ratio (3.5 million people and 50 million animals) to Mongolia, suffered its worst winter in 20 years. In response, the Ministry of Agriculture launched Operation Snow Relief, and supplied large amounts of fodder to snow-bound livestock across the country. In the Canterbury District of South Island, for example, more than 2,000 bales of hay and 1400 passengers, were ferried by the Royal New Zealand Air Force in 179 hours flying time (Wright 1992). Despite these efforts more than 1.2 million sheep died (Anon 1992).

Wright records that the total overall cost of Operation Snow Relief was estimated at around NZ\$ 37.5 million and that this was shared between the Ministry of Agriculture and farmers on a 50-50 basis. Whilst the Ministry of Agriculture managed the relief operation, every effort was made to involve farmer organisations, local authorities and community groups. In this way, local emergency preparedness was strengthened for future years. Such a collaborative approach lays a useful basis for addressing the issue of overstocking, which appears to lie at the root of the crisis.

Drawing from this experience, one can conclude that sustained, improved livestock production under Mongolia's harsh winter conditions is only possible if the state is prepared to continue to play a lead role, at least in the initial stages. The team is of the opinion, for example, that some form of fodder subsidy must be maintained, until such time as workable alternatives have been identified to safeguard herder communities in the Gobi. It may be that aimag and sum authorities can encourage wider herder participation in cost-sharing and thus reduce the overall financial burden to the state. As part of this process, for example, it may be possible to encourage the privatisation of fodder-making enterprises, through incentive schemes and production subsidies (in much the same way that farming in Europe and America is supported).

If herders in the Gobi are to be guaranteed continued access to fodder imported from other ecological zones of Mongolia, the team are concerned that herders/farmers in these production zones may face a critical shortage of appropriate hay-making equipment (tractors/horse-drawn and hand tools). As the highly mechanised state farms re-organise their production around more profitable enterprises, questions arise about the long-term sustainability of large hay-making units. For this reason, there is an urgent need to support the emergence of smaller-scale units, with

appropriate levels of mechanisation. In order to achieve this end, however, support will be required for the emergence of a regional agricultural engineering capacity.

In addition it is important that herders' access to different types of pasture and other key resources is guaranteed. The current high level of flexibility in the herding system safeguards a range of options, which is particularly important in harsh winters and dry summers.

In order to address fodder needs in the Gobi, a start was made to develop a framework to guide future research. The team are of the opinion that the following components require detailed further investigation, before the development of a regional fodder plan.

- quality requirements for different livestock species and ages
- quantity required in average/harsh years
- indigenous fodder production skills
- constraints associated with indigenous production
- storage issues - facilities/damage/labour availability/mechanisation
- alternatives to imported hay.

There is a range of alternatives to imported hay. These include expanding reserves, transference of local irrigation schemes from crop to fodder production, up-grading local key-resource pastures (tussock grass swamps) through reseeding, and finally water harvesting for establishing local fodder schemes.

5. RAINWATER HARVESTING

As part of the range of alternatives to imported hay, earlier PALD research suggests that 'the use of simple low cost rainwater harvesting techniques, especially in the drier areas, is a promising technical solution to part of the fodder problem' (PALD Working Paper 3, p13).

Overview of water harvesting systems

Modern technologies for obtaining and using water are concerned chiefly with the exploitation of river systems and the development of ground water by means of wells and boreholes. In areas where there are no rivers and ground-water is too deep to exploit economically, the direct collection of rainfall is one method which dispersed settlements have used to secure a water supply. The principle of collecting and using precipitation and rainwater run-off from a small catchment is referred to as 'rainwater harvesting' (Pacey and Cullis 1986).

The term rainwater harvesting derives from a more general name 'water harvesting', which was first used in Australia, and in its broadest sense can be defined as the 'collection of run-off (rainwater and snowmelt) for productive use'. Run-off may be collected from roofs and small ground catchments at one end of the scale, increasing to seasonal water courses, with turbulent and erosive run-off, at the other. This report explores the productive end-uses of the full range of water harvesting systems, for fodder production, based on the fact that rainfall in the Gobi is less than 180 mm/annum and consequently there is a need to explore run-off potential from larger catchments.

In addition to fodder production, alternative end-uses of harvested run-off water include domestic and livestock drinking water and the full range of plant production categories, including annual and perennial crops and trees (for fruit/browse or firewood). This report explores fodder crops and browse trees as the main end-uses. It may prove in the longer-term, however, that livestock drinking water, rather than fodder, is a more appropriate end-use for collected water.

Where the end-use of collected water is arable cropping, it is important to make relatively sophisticated assessments of crop water requirements, in order to design the water harvesting appropriately. In contrast, the water requirements for rangeland and fodder species are not usually calculated, as the objective is to improve performance, within given economic parameters, and to ensure the survival of plants from one season to another (Critchley and Siegert 1991). Consequently, efforts are simply made to concentrate available rainwater or snowmelt run-off from a larger catchments on to smaller cultivated areas, rather than fully satisfying plant water requirements. Examples can be found, therefore, of water harvesting techniques which flood pastures, resulting in substantial increases in fodder production in good years, whilst ensuring survival of perennial species in more arid years. Similarly, there are other techniques for concentrating rainwater run-off around the roots of browse trees, which significantly increase the rate of survival of young trees.

(Pacey and Cullis (1986) and Critchley and Siegert (1991) use 'catchment

length' to classify water harvesting techniques. Using this criteria there is a broad distinction between those systems which make use only of local flow and those which harvest channel flow from larger catchments. End-uses, as noted above, include both water supply for domestic and livestock drinking water, and plant production. The main categories for plant production are run-off farming (known in some regions as water ponding) and floodwater farming (or water spreading). Run-off farming is further divided, as indicated in table 5. Additional material on the characteristics and typical examples of each category is provided in figure 4.

Table 5. Basic water harvesting categories for fodder and browse production

Rainwater Harvesting - micro-catchments

Main characteristics:

- overland flow harvested from short catchment length
- catchment length usually less than 30 m
- normally no provision for overland flow
- run-off stored in soil profile
- plant growth is even

Typical examples:

- micro-catchments for trees
- contour bunds/ridges for trees and crops
- semi-circular bunds for fodder

Rainwater Harvesting - external catchment systems

Main characteristics

- overland flow or rill flow harvested
- catchment varies up to 500 m in length
- provision run-off stored in soil profile
- uneven plant growth unless land levelled

Typical examples:

- trapezoidal bunds for crops and fodder
- contour bunds for crops and fodder

Floodwater Harvesting

Main characteristics:

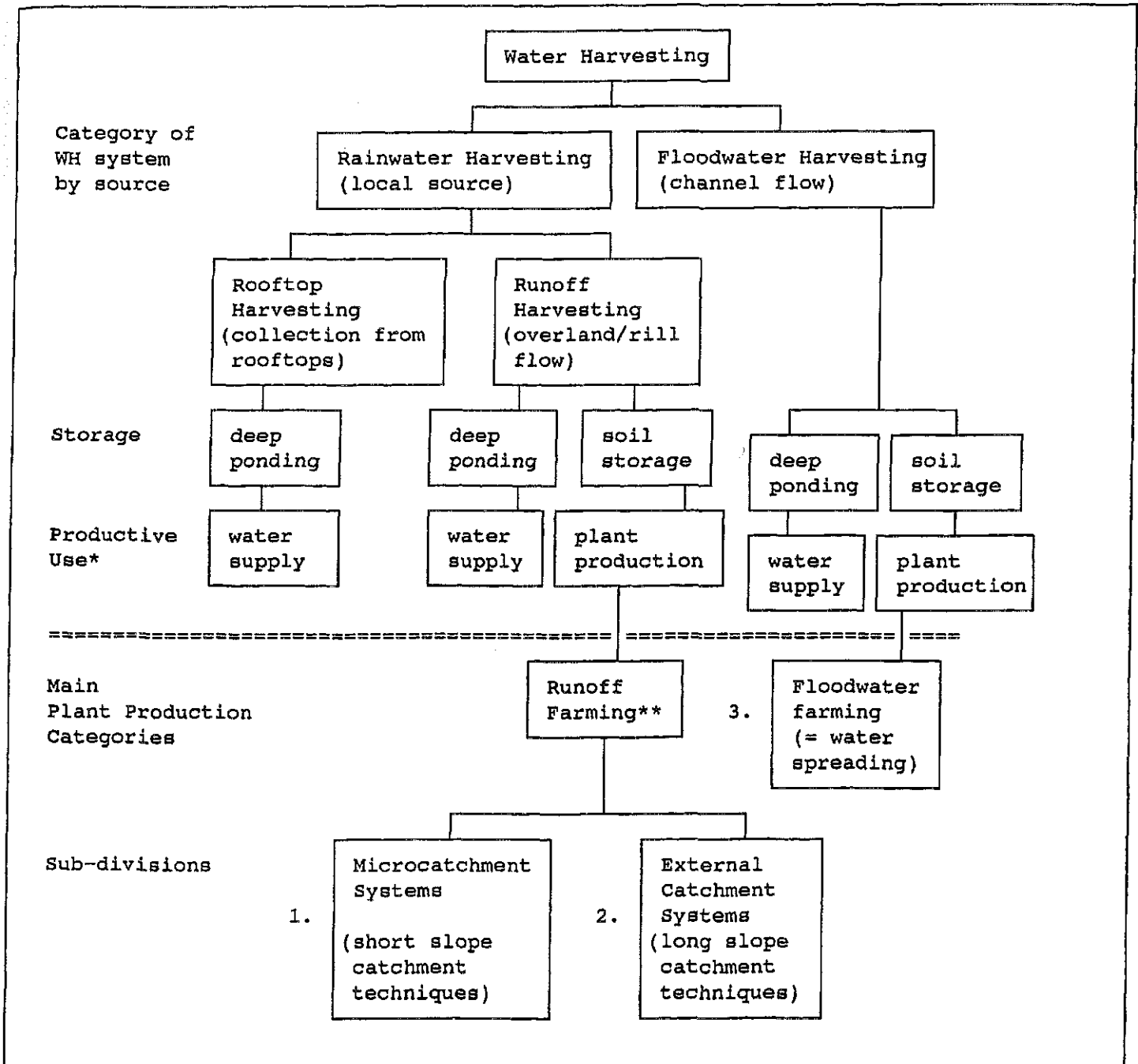
- turbulent and erosive channel flow
- long catchments (several kilometres)
- diversion structures
- dams or large bunds
- water stored in soil profile or reservoir

Typical examples:

- supplementary irrigation from dams for crops or fodder
 - spate irrigation for fodder
-

Figure 4

Classification of water harvesting techniques



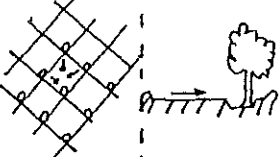
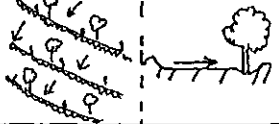
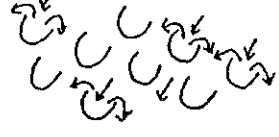
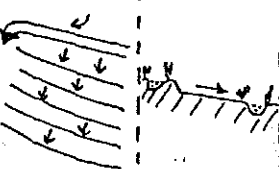
Notes:

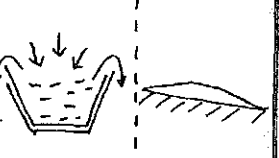
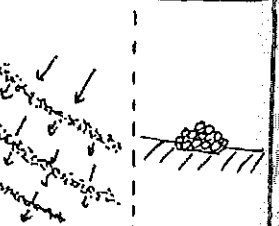
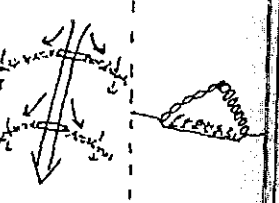

* Water supply systems (ie. ponded water) used for a variety of purposes, mainly domestic and stock water but also some supplementary irrigation.

** The term 'farming' (as in 'Runoff Farming') is used in its broadest sense -to include trees, agroforestry, rangeland rehabilitation, etc.

The FAO manual (Critchley and Siegert 1991) documents eight basic water harvesting techniques. These include micro-catchments; contour and semi-circular bunds; contour ridges and stone bunds; and trapezoidal, permeable and water spreading bunds. Descriptions, main uses, where appropriate and limitations are presented in summary form in table 6. Additional technical detail is attached in Appendix 4.

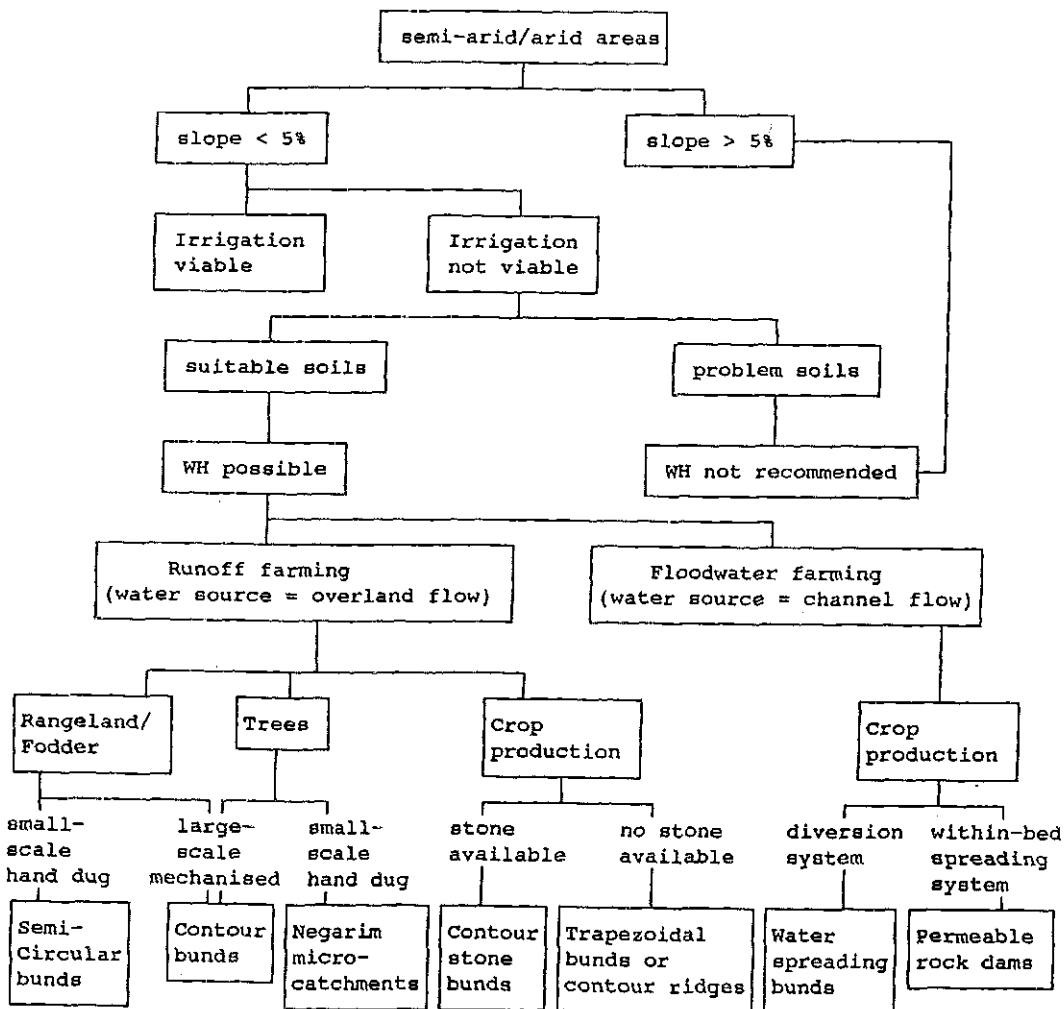
TABLE 6. SUMMARY CHART OF MAIN WATER HARVESTING TECHNIQUES

	Classification	Main Uses	Description	Where Appropriate	Limitations	
MICRO-CATCHMENTS	microcatchment (short slope catchment) technique	trees & grass	Closed grid of diamond shapes or open-ended 'V's formed by small earth ridges, with infiltration pits	For tree planting in situations where land is uneven or only a few trees are planted	Not easily mechanised therefore limited to small scale. Not easy to cultivate between tree lines	
CONTOUR BUNDS	microcatchment (short slope) technique	trees & grass	Earth bunds on contour spaced at 5-10 metres apart with furrow upslope and cross-ties	For tree planting on a large scale especially when mechanised	Not suitable for uneven terrain	
SEMI CIRCULAR BUNDS	microcatchment (short slope catchment) technique	rangeland & fodder (also trees)	Semi-circular shaped earth bunds with tips on contour. In a series with bunds in staggered formation	Useful for grass reseeding, fodder or tree planting in degraded rangeland	Cannot be mechanised therefore limited to areas with available hand labour	
CONTOUR RIDGES	microcatchment (short slope catchment) technique	crops	Small earth ridges on contour at 1.5m - 3m apart with furrow upslope and cross-ties <i>Uncultivated catchment between ridges</i>	For crop production in semi-arid areas especially where soil fertile and easy to work	Requires new technique of land preparation and planting, therefore may be problem with acceptance	

TRAPEZOIDAL BUNDS	external catchment (long slope catchment) technique	crops	Trapezoidal shaped earth bunds capturing runoff from external catchment and overflowing around wingtips	Widely suitable (in a variety of designs) for crop production in arid and semi-arid areas	Labour-intensive and uneven depth of runoff within plot	
CONTOUR STONE BUNDS	external catchment (long slope catchment) technique	crops	Small stone bunds constructed on the contour at spacing of 15-35 metres apart slowing and filtering runoff	Versatile system for crop production in a wide variety of situations. Easily constructed by resource-poor farmers	Only possible where abundant loose stone available	
PERMEABLE ROCK DAMS	floodwater farming technique	crops	Long low rock dams across valleys slowing and spreading floodwater as well as healing gullies	Suitable for situation where gently sloping valleys are becoming gullied and better water spreading is required	Very site-specific and needs considerable stone as well as provision of transport	
WATER SPREADING BUNDS	floodwater farming techniques	crops & rangeland	Earth bunds set at a gradient, with a "doglog" shape, spreading diverted floodwater	For arid areas where water is diverted from watercourse onto crop or fodder block	Does not impound much water and maintenance high in early stages after construction	

Understanding which techniques may be appropriate under which circumstances and their associated weaknesses is of critical importance, as the failure of many water harvesting projects can be traced to inappropriate application of certain techniques. For this reason, the FAO manual presents a simple flow chart which assists field-engineers to make informed decisions. This system selection chart is presented in figure 5.

Figure 5. SYSTEM SELECTION



Early technical and social assessments

Most water harvesting manuals focus on rainfall probability analysis and runoff coefficients, in order to arrive at basic design criteria. Such an approach requires the collection and analysis of considerable data over a long period frame as the data are frequently not available at the site level.

In contrast, the team sought to lay the basis of an alternative model which was developed in northern Kenya by one of the team members. The model abandons a 'blueprint' in favour of a site-by-site approach, in which field engineers work with the natural topographical features. Whilst demanding detailed knowledge of local topography and site characteristics, evidence suggests that structures are better designed and long-term maintenance costs are reduced. Furthermore, design criteria can be developed and refined in response to lessons learned.

Rooted in local knowledge, the perceptions and advice of local herders is central to understanding run-off characteristics and useful end-users. Whilst time in the field did not allow much progress along these lines, it was possible to start to develop a classification system for seasonal stream flow as shown in table 7.

Table 7. Seasonal run-off classification system for Gobi

<u>suda</u> or <u>shuda</u>	small wadi or run-off channel
<u>bulag</u>	water running in the channel
<u>jalga</u>	large run-off channel
<u>gorhky</u>	water running in the channel
<u>torim</u>	fresh water pan
<u>hygertain torim</u>	salty or brackish water pan
<u>ganga</u>	deep eroded channel
<u>gol</u>	river
<u>hunde</u>	valley

Note: This needs considerable further work and checking with Mongolian team.

Low and erratic rainfall patterns in the Gobi, together with run-off drainage patterns which vary from a high density of channel flow near the Gurvan Saikhan range to open plains with virtually no channel flow, necessitates the development of a set of flexible working guidelines, which will enable field-engineers to select, adapt and construct appropriate water harvesting structures, within technical parameters. The team is under no illusion that the development of

sustainable and viable water harvesting systems represents a major challenge.

In addition to assessing the full range of technical constraints, it is important not to under-estimate social and institutional factors which may impinge on technology choice and up-take. One way in which the team was able to make a small start in this area was to explore existing water catchment schemes in the Gobi. In particular, the team sought to understand how successful the 'technology transfer' route had been, as there is growing evidence that better results are achieved by working within existing technological parameters. It seems that this approach is often more efficient as it enhances existing skills.

Visits to four sites gave the team cause for concern, as at none was the potential end use for water being fully or even partially used. At Tsogt-tsetsy sum, for example, efforts had been made to impound run-off to flood pasture in a natural depression by constructing a large earth bund (125 m x 12 m x 10 m) across the single outlet. The team learned that following construction, good rains and subsequent floods had improved local pasture growth and also provided livestock with a useful pool of drinking water. Herders in the area were, however, less enthusiastic and had breached the bund to allow run-off water to follow its original course and thus water pastures nearer their winter shelters.

The second visit, to an irrigation scheme at Han Hongor sum was equally dispiriting. Water for the scheme is harvested from a large watershed and impounded behind a dam of substantial proportions. It appears that in previous years impounded water has been used to provide supplementary irrigation for an 18 ha site of mixed arable and fodder cropping. Unfortunately, this year, despite the considerable reserve of water still held in the reservoir, no crops or fodder had been produced. Indeed, water from the reservoir was left to run to waste across the open steppe, from an unstopped 8" irrigation feeder pipe. Two additional irrigation schemes (fed by spring-water) were in a similar state of dereliction and decay. The reasons for failure are not clear and it may be that the current round of economic restructuring is the cause, but it is also clear that much more needs to be understood about social institutions, land-use and tenure patterns.

Alerted to the problems of water harvesting in the Gobi, the team sought to look elsewhere around the world to consider water harvesting systems for fodder production. These are explored more fully below.

Lessons from Australia

There is a rapidly expanding body of documentation available on water harvesting, but unfortunately the bulk of it is associated with an alternative end-use, namely annual cereal cropping. There are, it seems, relatively few references available on water harvesting

schemes for fodder production. There have been water harvesting initiatives for fodder production in the Awash Valley of Ethiopia and Turkana, north-west Kenya, but neither appears to have been particularly successful. Amongst the reasons given for the failure of the schemes in Turkana is the fact that development workers 'acquire an enthusiasm for a particular technique which is pushed ahead regardless of local reactions' (Cullis and Pacey 1992). All too often, it seems, schemes are too ambitious, in terms of earth-movement and maintenance.

The only successful example of water harvesting for fodder production, identified to date, is a collaborative programme between the Soil Conservation Service and farmers in New South Wales, Australia. Research work carried out on texture contrast soils of western New South Wales, suggests that in drought years, repetitive heavy grazing has resulted in increased susceptibility to soil erosion. The result is scalding (Rhodes 1987). These scalded lands are unable to support stock and consequently have been of no economic value apart from their 'catchment' value, supplying run-off to livestock drinking water tanks. In 1984 the Marra Creek Waterponding Demonstration Programme was established, with a remit to rehabilitate 17,200 ha of scalded land (Penman 1987). Using techniques developed in Australia during the 1960-1970s, a variety of water-ponding (rainwater harvesting - external catchments) techniques were tested.

Due to high maintenance costs associated with bund breaches and smaller treated areas, decisions were taken to reduce the area of catchment and eventually to abandon catchments altogether in favour of a rainfed system. Circular banks are constructed using sophisticated road-graders, to contain rainwater ponding to a depth of between 7.5 and 10 cm (see Appendix 5). Good results have been achieved using this technique, when adequate attention is given to detail during the construction phase. Where bank failure has occurred it is usually at a single location and repair with a tractor mounted blade proven efficacious. Sensitive and responsive grazing management after ponding has ensured that the long-term rehabilitation of these scalds, and the associated economic benefits can be sustained.

An attempt has been made to evaluate the water-ponding programme from an economic perspective. Unfortunately, other criteria were ignored and consequently additional perceived benefits by the farmers were not recorded. The costs of rehabilitating 2,000 ha of scalded land (on one farm) were in the region of \$60,000. This work was financed from the farmers' cash reserves, a Soil Conservation Advance (or grant) and a 50 percent cash and 50 percent commercial loan. It appears that whilst the return on investment was less than that from alternative investment opportunities, a figure of 7 percent rate was achieved (Penman 1987). An added but un-recorded benefit to stockmen, which may be of particular interest to Mongolian planners, is the assertion that rehabilitated scald-land can carry livestock through an extended dry season more easily than degraded land.

6. A PLANNING FRAMEWORK FOR WATER HARVESTING IN THE GOBI

In order to make full use of lessons learned in sub-Saharan Africa and Australia, it is important that detailed attention be given to proper research, planning and scheduling of any proposed water harvesting interventions in Mongolia. Whilst it is clear that there are benefits from water harvesting, both in terms of increased fodder production and possibilities for livestock and human drinking water, caution must be exercised if costly mistakes are to be avoided. For this reason, the team has adapted a planning framework originally developed at the Centre for Development Co-operative Services at the Free University of Amsterdam, which puts the question of developing water harvesting in the context of a broader fodder programme.

Coordinating body to develop a national fodder plan

A co-ordinating body, consisting of key officials from the Ministry of Agriculture and associated research institutes, could take forward the development of a national fodder plan. The role of this body could be as follows:

- To agree institutional responsibilities for co-ordinating and developing a national fodder plan.
- To identify priority fodder deficit areas and undertake fodder audits, which document regional problems, priorities, constraints, skills and resources available.
- To undertake a series of detailed case studies, which identify local issues and concerns.
- To analyze all material and draft a national fodder plan, which will be continually monitored, reviewed and modified over time. Such a plan will include all aspects of scientific research, policy and field programmes.
- To establish specialist units to carry forward and develop responsive research, policy and field programmes, including a water harvesting unit.

One of the main attractions of such a plan is that the water harvesting team would benefit from opportunities for interaction with other specialist units and therefore be able to make more informed decisions. The team are aware, however, that the creation of a national fodder plan represents a major undertaking, which will involve many actors and take up considerable time. Furthermore, water harvesting is only a small component of a broader plan and as such could be pushed forward in an experimental way, without necessarily waiting until there is a national fodder plan. Thus it is probably more realistic to suggest that a specialist water harvesting unit can proceed in parallel without waiting for that to happen.

Specialist water harvesting unit

The responsibilities of the water harvesting unit would be as follows:

- To select staff and invest in training in order that the team are able to work easily with herders to collect and analyze data, implement pilot projects and monitor progress. Use should be made of exchange visits to learn from mistakes and successes in other countries. Staff need also to be adequately resourced with information (books and videos etc).
- To select a small number of sum in which rainwater harvesting trials with herders can be piloted. Collect information from local herders on herding strategies, seasonal pasture management and social organisation at the suur/khotail level.
- To agree with herders possible water harvesting interventions which can be piloted at the local level. Thought should be given at this stage to addressing relevant policy issues including incentives, which would encourage broader participation in such work. Every effort should be made to incorporate fully indigenous skills (selection and knowledge of local sites/animal draught capacity/indigenous fodder supply/etc).
- To monitor and review all progress in the light of herder perceptions and make necessary adjustments as and when required.
- To establish alongside these initiatives a separate research team to collect and collate detailed technical information from a series of water harvesting trial and demonstration plots.

Timetable of activities

An outline timetable of activities for the specialist water harvesting unit is as follows:

Phase 1: Winter and spring 1993/94

Institutional arrangements to enable the formation and resourcing of such a unit.

It is suggested that field trials could best be carried out in both the steppe and Gobi zones and hence it would be necessary to identify institutions in these zones which would be prepared to develop a collaborative research programme. As a result of discussions with the director of the Gobi Research Institute at Bulran the team suggests that this institute, in Bulran sum, would be an ideal venue to undertake the research trials for the Gobi zone.

Phase 2: Summer 1994

Research component:

Sites for water harvesting trials should be selected in both the steppe and Gobi zones, covering a range of different slopes and soil types, in order to gain an understanding of the characteristics of different run-off regimes. Once these have been agreed, it would be the responsibility of the overall director of the unit to appoint a co-ordinator for the research programme.

The co-ordinator would:

- establish two small research programmes (one in the steppe and another in the Gobi zones);
- undertake a detailed review of water harvesting literature;
- arrange and visit selected water harvesting projects;
- develop an innovative programme of water harvesting trials to collect, synthesise and disseminate data on:
 - local rainfall (intensity, duration, variability and probability);
 - soils (texture, structure, depth, salinity and infiltration rate);
 - rainfall and run-off relationship (soils, vegetation, slope and catchment size) through the measurement of surface run-off under controlled conditions. Run-off plots should, for this reason, be established (see Appendix 6). These data should provide an assessment of seasonal run-off and hence the potential for the increased production of indigenous fodder species (for summer grazing, winter standing fodder and possibly also for hay).
- select and test a range of water harvesting structures in order to determine the associated construction costs, maintenance requirements and impact on fodder yield of each technique. In particular, contour stone, semi-circular, and water spreading bunds should be tested (see Appendix 4).

Autumn/winter of 1994/5

Activities for the autumn and winter should include:

- collation and analysis of data;
- completion of literature review and additional visits to water harvesting projects;
- preparation of 5 year strategic plan and funding proposals.

Phase 3: Summer of 1995 to 2000

Provided adequate funding has been secured, it should be possible to expand the water harvesting programme during the spring and summer of 1995, to include a small field unit, in addition to the research programme. The establishment of such a unit is considered to be of central importance in engaging herders in a meaningful dialogue and refining water harvesting systems to specific end-uses. This team should be made up of extension workers who feel at ease living with herding communities for extended periods and be encouraged to adopt a flexible approach in which the fear of failure should not over-rule innovation.

Such a unit would:

- establish a dialogue with selected herder groups in both the steppe and Gobi zones and undertake needs assessment surveys
- carry out household fodder audits;
- survey existing skills in related technical fields such as animal transport and traction (for earth moving and bund building) and availability of local blacksmithing for tool production;
- collect other socio-economic data as required;
- encourage and manage herder group visits to the water harvesting trial sites;
- assist herder groups seeking to establish their own water harvesting plots for either fodder production or the collection of run-off for livestock drinking water;
- assist herder groups to monitor and evaluate water harvesting initiatives using herder criteria;
- identify appropriate dissemination flows for this information in order to offer to other herder groups options for improved fodder production.

As the fund of knowledge is built up, the field unit should work together with the research team to address important policy issues, in particular to explore with policy makers a range of incentives which may encourage the wider uptake of appropriate and proven water harvesting technologies.

References:

Anon, 1992, "Storm Kills Sheep", Midlands Farmer and Grower, November 1992.

Coffey MPW Pty Ltd., 1992, Livestock Feeds Improvement Project, TA.NO 1649-MON, Interim Report.

Critchley, W., and Siegert, K., 1991, Water Harvesting: A Manual for the Design and Construction of Water Harvesting Schemes for Plant Production. Rome: Food and Agriculture Organization of the United Nations.

Cullis, A., and Pacey, A., 1992, A Development Dialogue: Rainwater Harvesting in Turkana. London: IT Publications.

Pacey, A., and Cullis A., 1986, Rainwater Harvesting: The Collection Or Rainfall And Run-off In Rural Areas, London: IT Publications.

Penman, P., 1987, "An Economic Evaluation of Waterponding", Journal of Soil Conservation pp 68-72. New South Wales, Australia.

Policy Alternatives for Livestock Development in Mongolia, 1991. Working Paper No. 2: Transformation of a Pastoral Economy: a local view from Arhangai and Dornogobi Provinces.

Policy Alternatives for Livestock Development in Mongolia, 1991. Working Paper No. 3: Liberalisation of the Mongolian Pastoral Economy: Policy Issues and Options.

Toulmin, C., 1983, Economic Behaviour of Livestock Keeping Groups in Africa. Occasional Paper No. 25, School of Development Studies, University of East Anglia.

Rhodes, D., 1987, "Vegetation Response and Productivity Improvements Under Waterponding". Journal of Soil Conservation, pp 62-67 New South Wales, Australia.

Swift, J., 1991, "Traditional Pastoral Milk Products in Mongolia". Appropriate Technology, 18:(1).

Wright, M., 1992, "Royal New Zealand Air Force Adds Up Costs of Stock Relief". Country Times: Southern Farming and Lifestyle Magazine, August, 1992.

APPENDIX 1

MONTHLY RAINFALL DATA FOR THREE SUM : BULRAN, GURVAN
SAIKHAN AND TSOGT-TSETSY

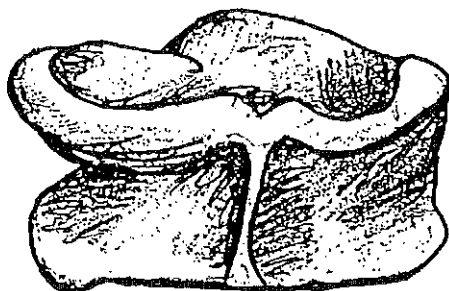
YEAR	MONTH												ANNUAL 1-12
	1	2	3	4	5	6	7	8	9	10	11	12	
Bulran													
1981	4	0	11	-	6	17	29	34	6	11	7	1	126
1982	0	-	2	3	8	6	7	38	10	2	5	5	86
1983	5	4	1	0	2	0	21	42	37	20	2	0	134
1984	0	2	1	2	1	19	13	4	5	2	3	4	57
1985	1	1	1	4	5	5	35	6	25	0	7	-	90
1986	6	3	8	2	6	13	41	25	28	2	7	5	152
1987	6	0	6	0	3	3	32	23	21	28	7	3	132
1988	3	3	3	1	15	0	13	17	4	2	0	0	62
1989	0	1	9	22	6	2	12	14	15	2	4	3	90
1990	8	0	23	10	16	20	79	16	12	10	3	1	190
1991	2	3	4	4	3	83	4	60	16	2	0	6	187
1992	5	1	5	1	20	5	25	13	9	2			86
Gurvan Saikhan													
1981	0	-	-	-	0	0	13	43	-	-	3	0	59
1982	0	-	-	0	2	-	19	-	14	1	2	1	39
1983	0	0	x	0	16	13	11	28	26	5	0	x	99
1984													
1985	1	2	0	8	0	8	61	25	11	1	2	0	119
1986	1	0	2	2	6	44	19	28	13	1	4	5	126
1987	2	1	2	0	20	2	26	24	45	29	3	1	153
1988	9	2	0	2	8	17	30	16	3	17	0	0	105
1989	0	3	0	3	0	9	17	16	2	0	1	3	54
1990	1	2	0	1	23	5	92	25	18	5	7	1	182
1991	3	0	8	0	0	12	6	47	16	-	-	2	94
1992	0	2	0	18	6	5	38	37					106
Tsogt-tsettsy													
1981	4	2	4	2	1	13	21	19	4	3	6	-	79
1982	0	1	0	0	2	11	22	34	3	1	1	2	77
1983	2	1	2	2	5	18	50	29	34	-	1	-	144
1984	0	3	0	2	0	22	68	35	2	0	2	2	136
1985	0	6	1	12	2	10	54	13	23	x	2	0	122
1986	1	1	1	0	6	11	x	30	94	1	1	3	149
1987	0	0	0	0	9	13	53	90	19	43	2	0	229
1988	6	1	2	0	8	11	46	70	6	8	0	0	158
1989	1	1	1	7	0	2	4	6	16	x	1	1	40
1990	5	0	5	2	13	11	48	15	0	2	0	0	101
1991	1	2	4	6	2	30	37	24	11	x	0	4	121
1992	5	2	-	-	5	16	29	12					69

Notes : 'x' ~ no data Hydrometeorological Research Institute, Mongolia.

APPENDIX 2

SHAGAA: AN OPTION FOR PARTICIPATORY RURAL APPRAISAL

Shagaa is a game which appears to have some 20 different forms. The counters for this game are the small knucklebones of sheep and goats, as shown below. In addition each counter can take on a number of different functions as each face of the bone represents a different livestock type. Thus one side represents a camel, another a horse and so on for sheep, goats and cattle.



Most households appear to have a small bag of shagaa totalling some 30-40 counters. As such there is a possibility to use this game for participatory or rapid rural appraisal ranking exercises. The team used the game to rank winter livestock losses with household members.

APPENDIX 3 INDIGENOUS FODDER CONSERVATION TECHNIQUES

Local fodder production in Mongolia has been fully researched and is documented in 'Methods of Fodder Production' 1980, by Professor Serendolam, Dr. Badam, Dr. Jigjidsuren and research worker Hukku; it was published by the State Publishing House in Ulaanbaatar.

In this publication, details were given of a number of hand-preparations peculiar to the Gobi region. They are as follows:

- owse (hay): both green and dried hay is collected by women in the Gobi. Longer-stemmed grasses growing in depressions or along natural drainage channels were particular favourites. Lengths (1 m) of twisted hay were stored on ger roofs and used as a winter supplement.
- zooda (a simple concentrate): made from a variety of herbs and onion species (Alium mongolicum, A. polycresum, and A. odorum) which were chopped or ground and mixed with either salt and/or aarts (whey). Two samples of zooda were returned to the UK and analyzed by Farmlab: Whetstone Magna, Lutterworth Rd., Whetstone, Leicester (see below).
- use is also made of the rumen contents of slaughtered animals. This semi-digested grassy material is mixed with aarts, additional grasses, stuffed back into the rumen and stored until winter.

Results of laboratory analysis of zooda samples:

The results of the analysis of two zooda samples are as follows:

Sample A: Ash 9.3 percent Crude Protein 26.9 percent Oil 1.4 percent Fibre 12.1 percent Mad Fibre 25.4 MJ/KG

Very high estimated energy values with valuable level of crude protein. Energy and protein need 'diluting' with fibre, to balance and prevent nutrient wastage.

Sample B: Ash 28.8 percent Crude Protein 40.6 percent Oil 14.1 percent Fibre 3.2 percent Mad Fibre 15.2 MJ/KG

As above. Also high ash content which would indicate that the oil is the dominant energy source. Requires major dilution with fibre.

Farmlab staff make the point that in order for ruminants to make full use of these concentrate feeds, it is essential to feed them with large amounts of roughage and fibre. Ruminants feeding on low quality, standing fodder in Mongolia will necessarily have high fodder intakes.

APPENDIX 4 ADDITIONAL TECHNICAL DETAIL OF EIGHT WATER HARVESTING TECHNIQUES

The details given in this Appendix have been abstracted from the FAO Water Harvesting Manual (Critchley and Siegert 1991) almost verbatim. We have made some amendments where our thinking differs from the manual.

Micro-catchments

Micro-catchments are used mainly for tree growing, in areas of rainfall as low as 150 mm per annum. Soils, however, need to be deep in order to store harvested water.

Each micro-catchment consists of a catchment area (normal range between 10 m and 100 m) and an infiltration pit, in which the tree is planted (see figure on following page). Bund height around the micro-catchment needs to be adequate to avoid overtopping and is therefore dependent on prevailing ground slope and the selected size of the catchment area. Whenever possible, bunds should be grassed to avoid erosion.

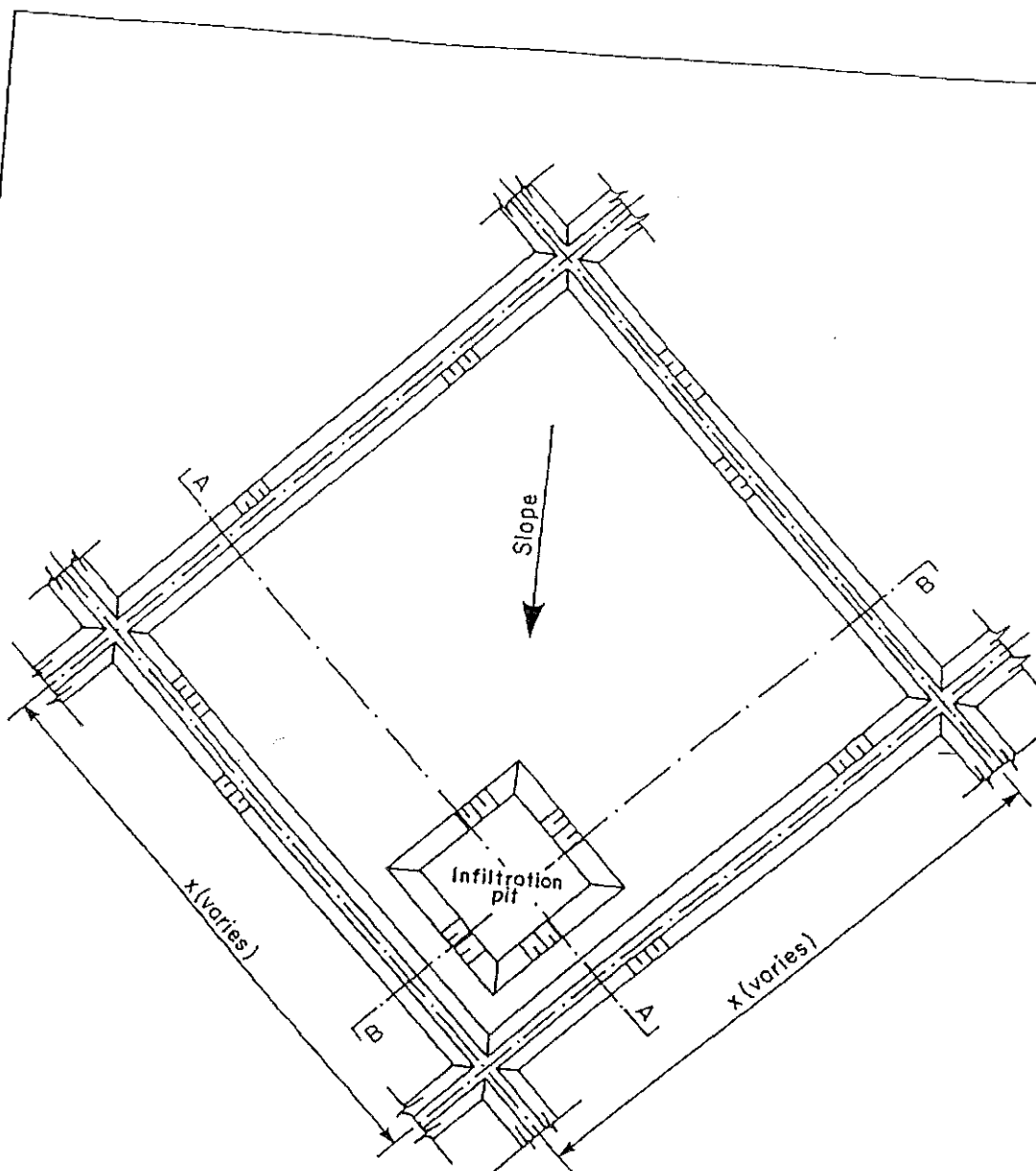
The table below recommends values for pit dimensions. Excavated soil from the pit should be used for the construction of the bunds.

QUANTITIES OF EARTHWORKS FOR MICROCATCHMENTS

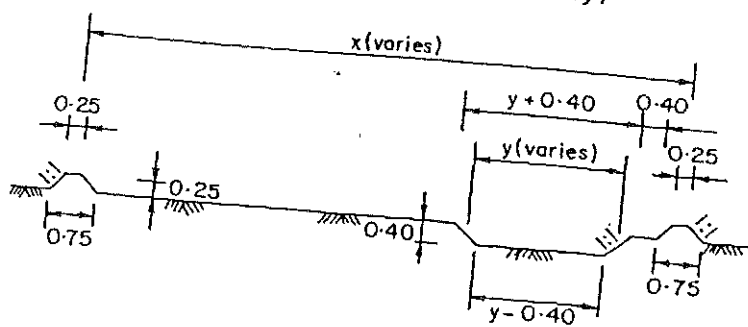
(1) Size Unit Microcatchment (m ²)		(2) Size Infil- tration Pit (m)		(3) Ground Slopes Suitable for 25 cm Bund Height*	(4) Volume Earthwork Per Unit** (m ²)	(5) No. Units Per ha	(6) Earthworks m ³ /ha
Sides (x)	Area	Sides (y)	Depth				
3 m x 3 m = 9 m ²		1.4 x 1.4 x 0.4		up to 5%	0.75	1110	835
4 m x 4 m = 16 m ²		1.6 x 1.6 x 0.4		up to 4%	1.00	625	625
5 m x 5 m = 25 m ²		1.8 x 1.8 x 0.4		up to 3%	1.25	400	500
6 m x 6 m = 36 m ²		1.9 x 1.9 x 0.4		up to 3%	1.50	275	415
8 m x 8 m = 64 m ²		2.2 x 2.2 x 0.4		up to 2%	2.00	155	310
10 m x 10 m = 100 m ²		2.5 x 2.5 x 0.4		up to 1%	2.50	100	250
12 m x 12 m = 144 m ²		2.8 x 2.8 x 0.4		up to 1%	3.25	70	230
15 m x 15 m = 225 m ²		3.0 x 3.0 x 0.4		up to 1%	3.50	45	160

* These ground slopes allow construction of a bund of 25 cm height throughout its length. Above these gradients the bund should be constructed relatively higher at the bottom (below the pit) and lower upslope. Table 17 gives the height of the bund below the pit for given microcatchment sizes.

** Calculation of earthworks per unit includes only two of the sides around the catchment: the other two sides are included in the microcatchment above.
Does not include earthworks required for diversion ditch (which is 62.5 m³ for each 100 metre length).



PLAN
(Planting step omitted for clarity)



SECTIONS. A-A, B-B

microcatchment: details for 0.25 m bund size

Contour bunds

Contour bunds are also used mainly for tree planting (but also annual crops) and are really a simplified form of micro-catchment. Construction can, however, be mechanised and therefore the technique is suitable for implementation on a larger scale. Also, due to the fact that less earth is moved, the technique is more cost effective (see table below). The bunds follow the contour at 5-10 m spacing and with small tie ridges reduce the movement of water along the contour (see figure below).

Contour bunds have been used successfully for trees under the following conditions: rainfall from 200-750 mm per annum, on gentle slopes of less than 5 percent. Contour bunds are not suitable for uneven or badly eroded land.

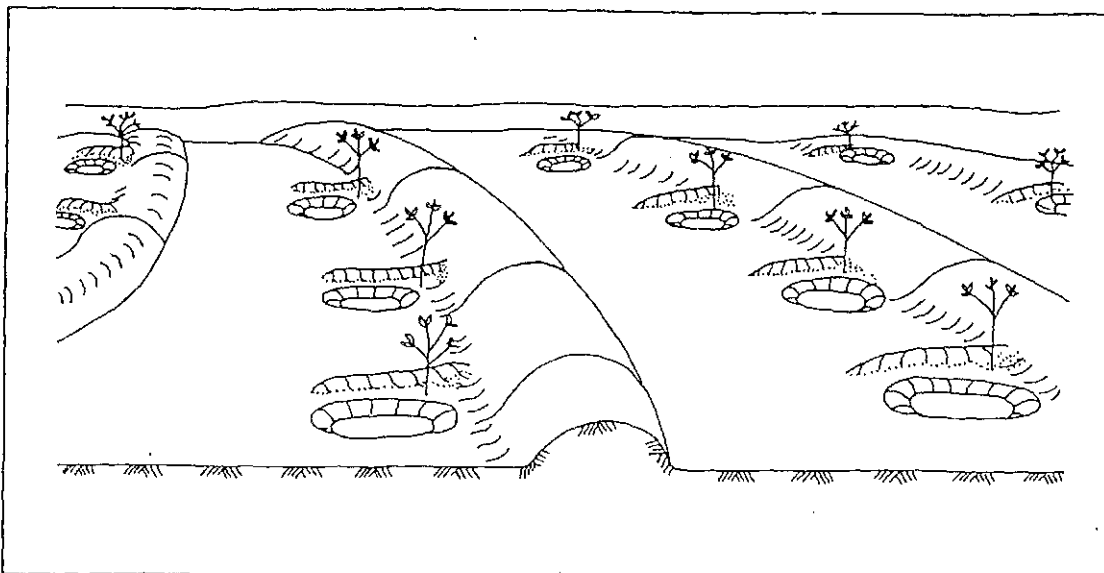
Bund heights vary, but are frequently in the order of 20-40 cm depending on the prevailing slope. As bunds are often made by machine, the shape will depend on the earth-moving equipment used. This said, however, it is recommended that the base width of the bund is at least 75 cm. Cross-ties should be at least 2 m long with a spacing of 2-10 m.

Excavated soil from the infiltration pit in which the tree is planted is used for the cross-tie and pits of 80 cm x 80 cm and 40 cm deep have been usually found sufficient.

As with micro-catchments, maintenance will in most cases be limited to the repair of the bunds early in the first season. It is essential, however, that these are undertaken or rills and gullies will reduce the effectiveness of the technique and tree establishment reduced.

Size Unit Microcatchment			Volume Earthworks per Unit (m ³)	No. Units per ha	Earthworks m ³ /ha
Bund spacing	Tie spacing	Area (m ²)			
5 m	2 m	10	0.5	1000	500
5 m	5 m	25	0.9	400	360
5 m	10 m	50	1.5	200	300
10 m	2.5 m	25	0.6	400	240
10 m	5 m	50	0.9	200	180

QUANTITIES
OF EARTHWORKS



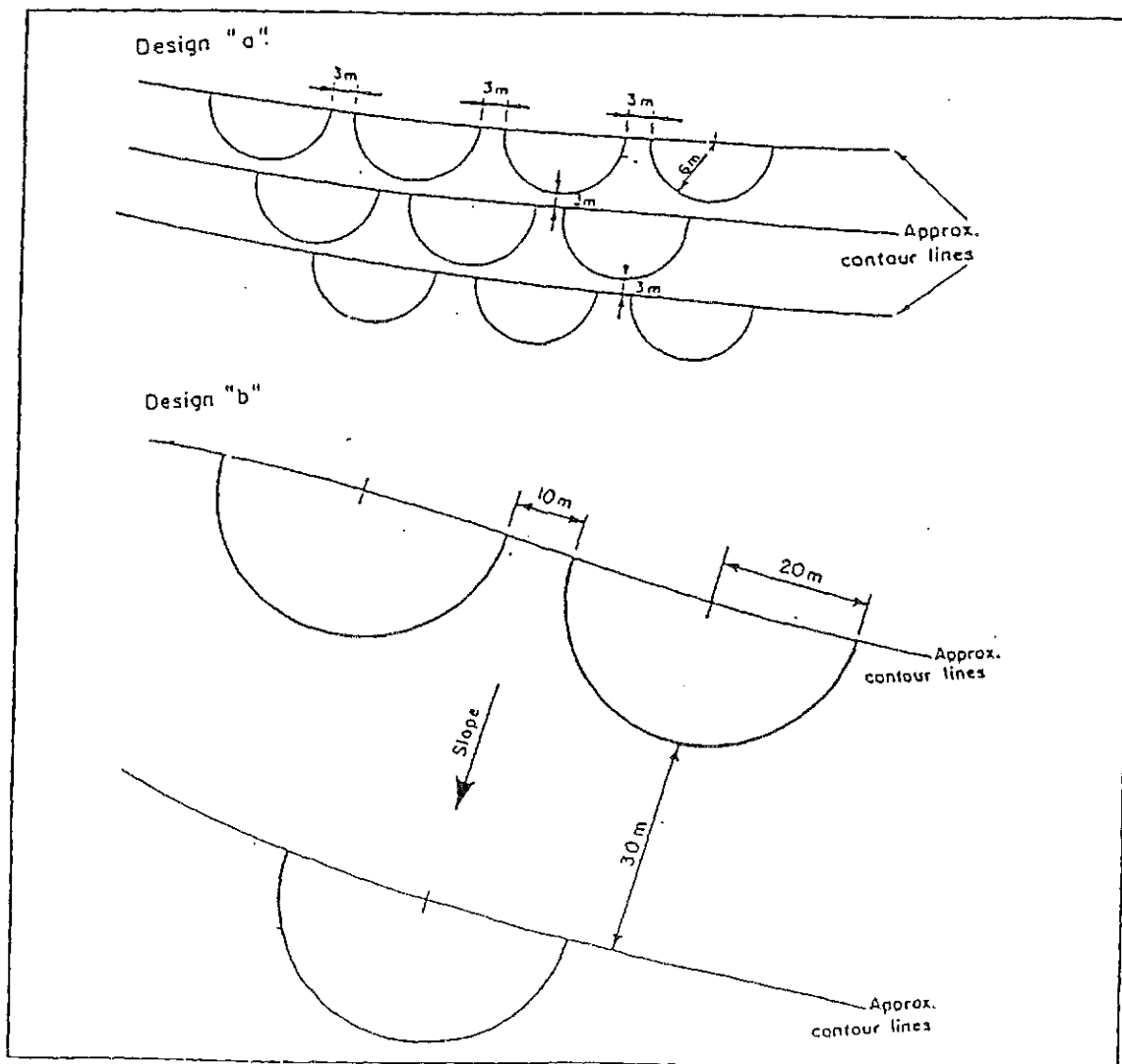
Contour bunds for trees

Semi-circular bunds

Semi-circular bunds are, as the name suggests, earth embankments, of varying dimensions, in the shape of a semi-circle, and used for fodder production, growing trees and occasionally for growing crops. They are, regarded as a quick and easy method of improving rangelands as, in terms of impounded area to volume of earth moved, they are the most cost effective structure of the 8 techniques listed in this report.

Semi-circular bunds for fodder production have been used effectively under the following conditions: rainfall of 200-750 mm per annum; slopes below 2 percent. Structures can either be sited closely together in wetter areas, provided there is even terrain or larger more widely spaced structures in drier areas. For the former, radii of 6 m appear most effective whilst for the latter radii of up to 20 m have been tested. In each case, lines of contour bunds are staggered as shown in the figure below.

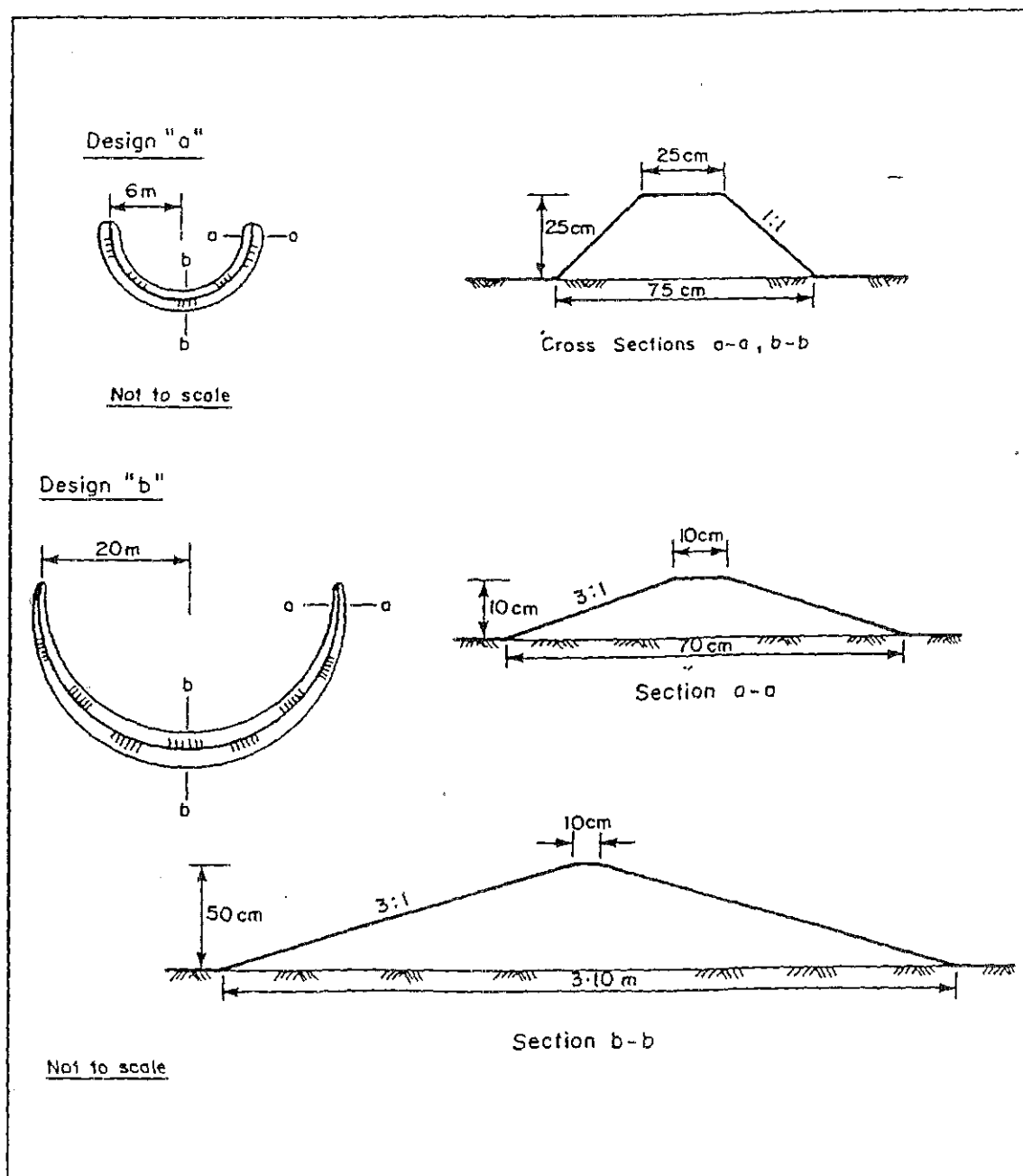
Quantities of earthworks involved and dimensions of the two types of bunds (larger and smaller) are also shown below. As with all other earth structures, the critical period for maintenance is when the first rainstorms arrive after construction, when bunds are not yet properly consolidated. Any breakages must be repaired immediately and attention given to compaction. It may well be necessary to install a cut-off drain above the bunds to deflect storm water away from the site.



Semi-circular bunds: field layout

QUANTITIES OF EARTHWORKS FOR SEMI-CIRCULAR BUNDS

Land slope	Radius (m) (1)	Length of bund (m) (2)	Impounded area per bund (m^2) (3)	Earthworks per bund (m^3) (4)	Bunds per ha (5)	Earthworks per ha (m^3) (6)
Design "a" up to 1.0%	6	19	57	2.4	73	175
Design "b" up to 2.0%	20	63	630	26.4	4	105
4.0%	10	31	160	13.2	16	210

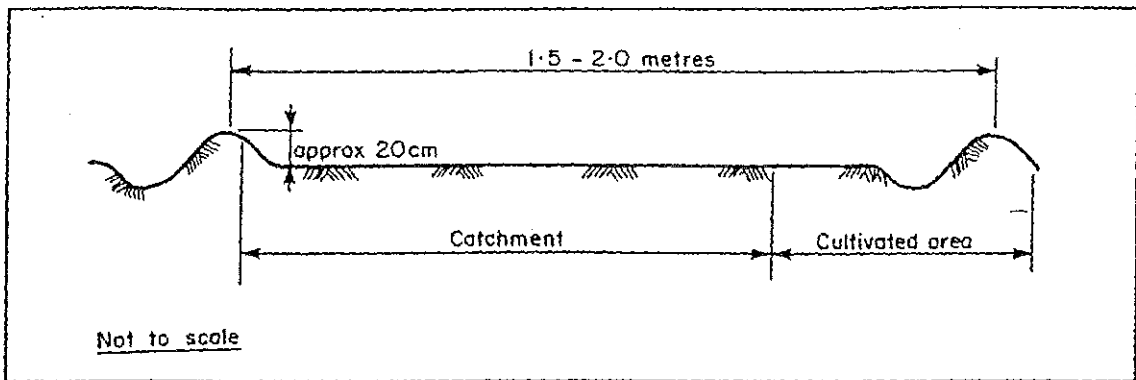


Semi-circular bund dimensions

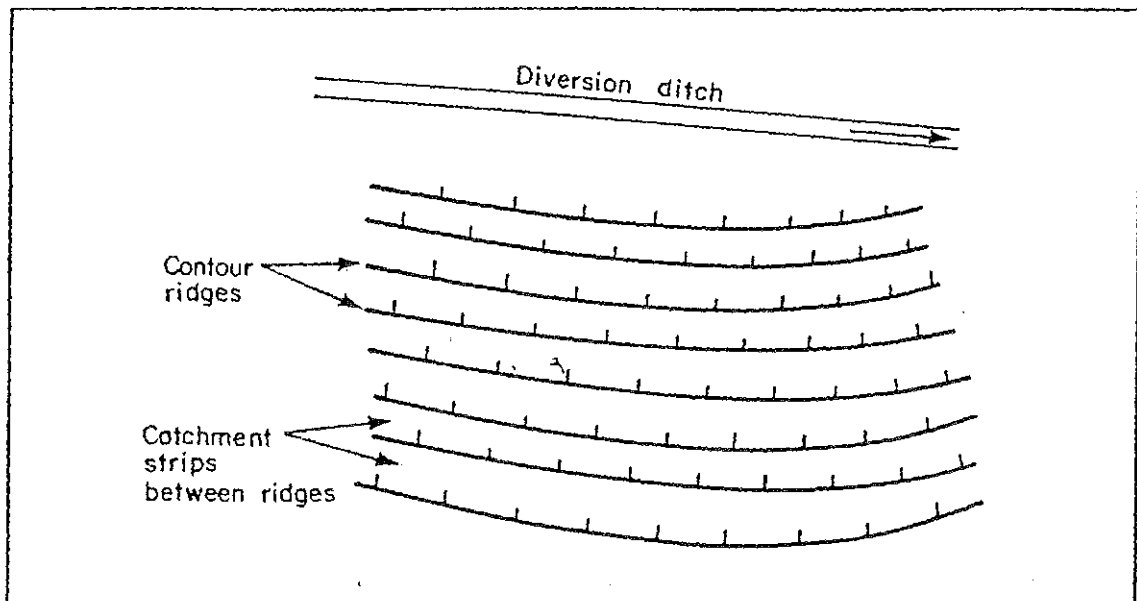
Contour ridges for crops

Another microcatchment technique, this is similar to contour bunds for trees, except that the spacing between the bunds is reduced to 1-2 m. Run-off from the catchment between the bunds is stored in a furrow just above the ridge, in which annual crops are planted. This technique has not been widely developed.

Quantities of earthwork involved and diagrams of field layout and contour ridge dimensions are given below:



Contour ridge dimensions



Contour ridges: field layout

Trapezoidal bunds

Trapezoidal bunds are used to enclose much larger areas (up to several ha) and to impound larger volumes of water, which is harvested from an external catchment or 'long-slope' catchment. Overflow discharges around the wingtips of the side bunds or wingwalls. Crops are planted in the enclosed area.

This is a traditional technique in many parts of arid and semi-arid sub-Saharan Africa. The concept is simple and not unlike the semi-circular bunds in which three sides of a plot are enclosed, whilst the fourth is left open to allow run-off to enter. The simplicity of design and the relative ease of construction are amongst the main advantages associated with this technique.

Trapezoidal bunds have been successfully used under the following conditions: 250-500 mm rainfall per annum; good, non-cracking (clay) soils; and slopes from 0.25-1.5 percent. The technique is therefore dependent on low ground slopes, for on steeper slopes large quantities of earth movement is required.

Traditional forms of trapezoidal bunds are found in Sudan and Somalia. In Sudan the layout of the bunds is rectangular with wingwalls extending up-slope at right angles to the base slope, as shown in the diagram below. An alternative design developed in Turkana District, NW Kenya is also shown, together with standard cross-section and quantities of earthworks involved.

The main problem is bund breaches. Whilst these are often the result of poor compaction, some are caused when efforts are made to impound run-off from large catchments. It may also be the case that several large storms within a relatively short period cause overtopping of the base bund and subsequent breaching. For this reason, it may be advisable to install cut-off or diversion drains above each bund, which can be opened as necessary. Similarly, wing-bunds tips can be protected with stone.

QUANTITIES OF EARTHWORKS FOR TRAPEZOIDAL BUND

Slope (%)	Length of base bund (m)	Length of wingwall (m)	Distance between tips (m)	Earthworks per bund (m ³)	Cultivated area per bund (m ²)	Earthworks per ha cultivated (m ³)
0.5	40	114	200	355	9600	370
1.0	40	57	120	220	3200	670
1.5	40	38	94	175	1800	970

Note: Where diversion ditches or collection arms are required these add 62.5 m³ for each 100 m length.

See detail on Fig. 43

GENERAL EQUATION FOR "x"

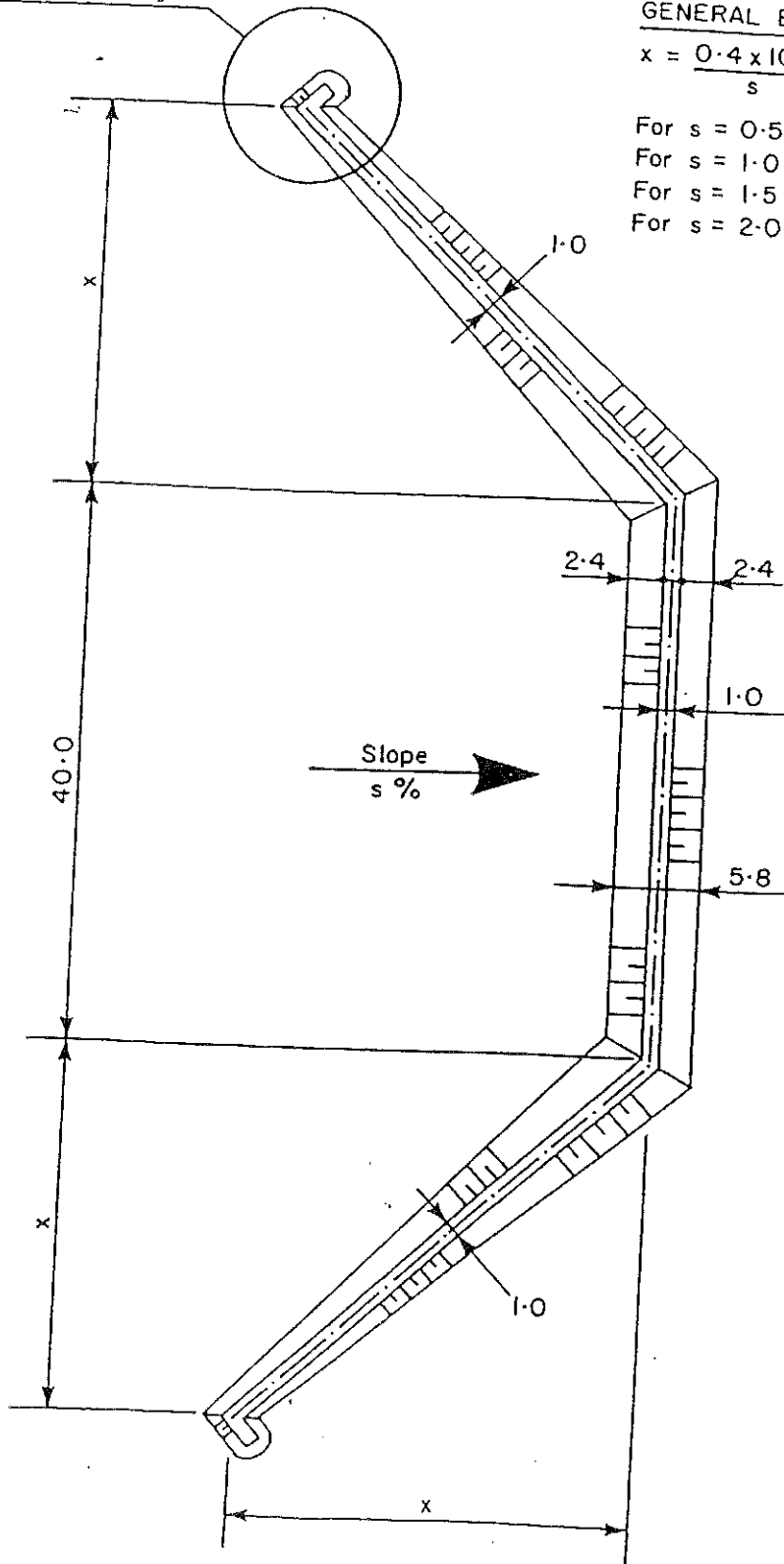
$$x = \frac{0.4 \times 100}{s} \text{ where } s = \text{slope } \%$$

For s = 0.5 % (1 in 200), x = 80m

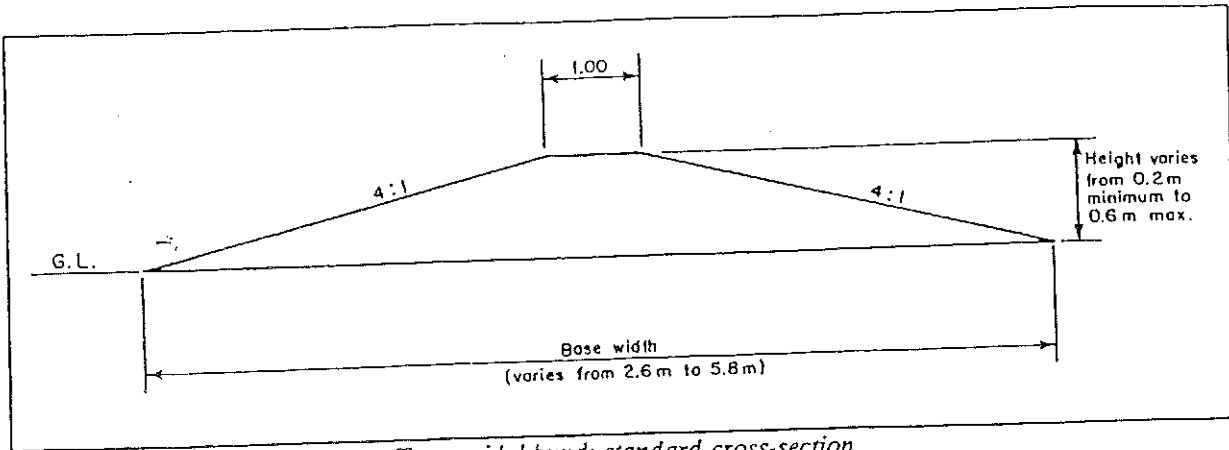
For s = 1.0 % (1 in 100), x = 40m

For s = 1.5 % (1 in 67), x = 27m

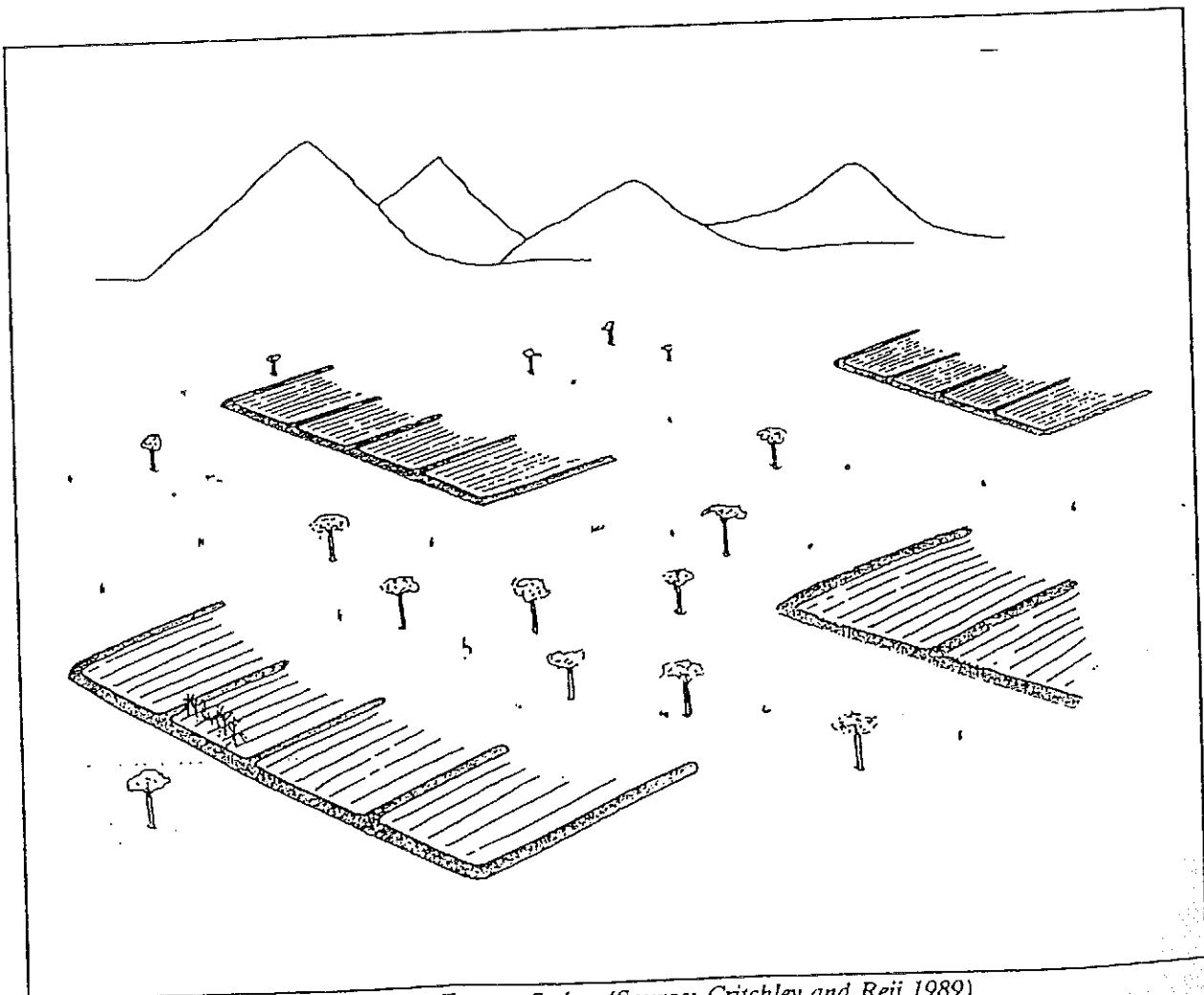
For s = 2.0 % (1 in 50), x = 20m



Trapezoidal bund dimensions



Trapezoidal bund: standard cross-section



"Teras" system, Eastern Sudan (Source: Critchley and Reij 1989)

Contour stone bunds

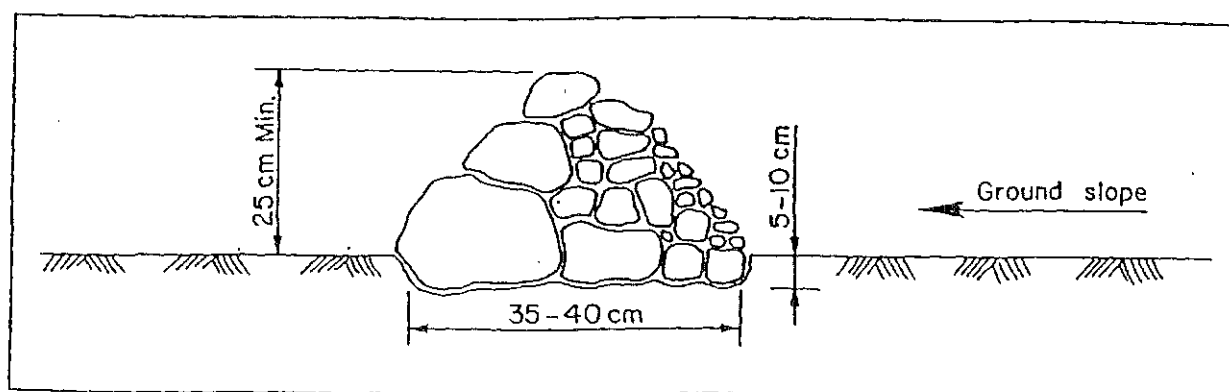
Contour stone bunds are used to slow down and filter run-off, thereby increasing infiltration and reduce soil erosion. The harvested water and sediment contribute directly to improved crop performance. The technique has been shown to be well suited to small-scale application on farmer's fields. Given adequate stones it can be implemented quickly and cheaply.

Stone bunding is a traditional practice in many parts of West Africa, but recent improvements have been made with the siting of stone bunds on the contours. As the stones only filter the water there is little maintenance. It is a technique which is popular and readily acquired by villagers.

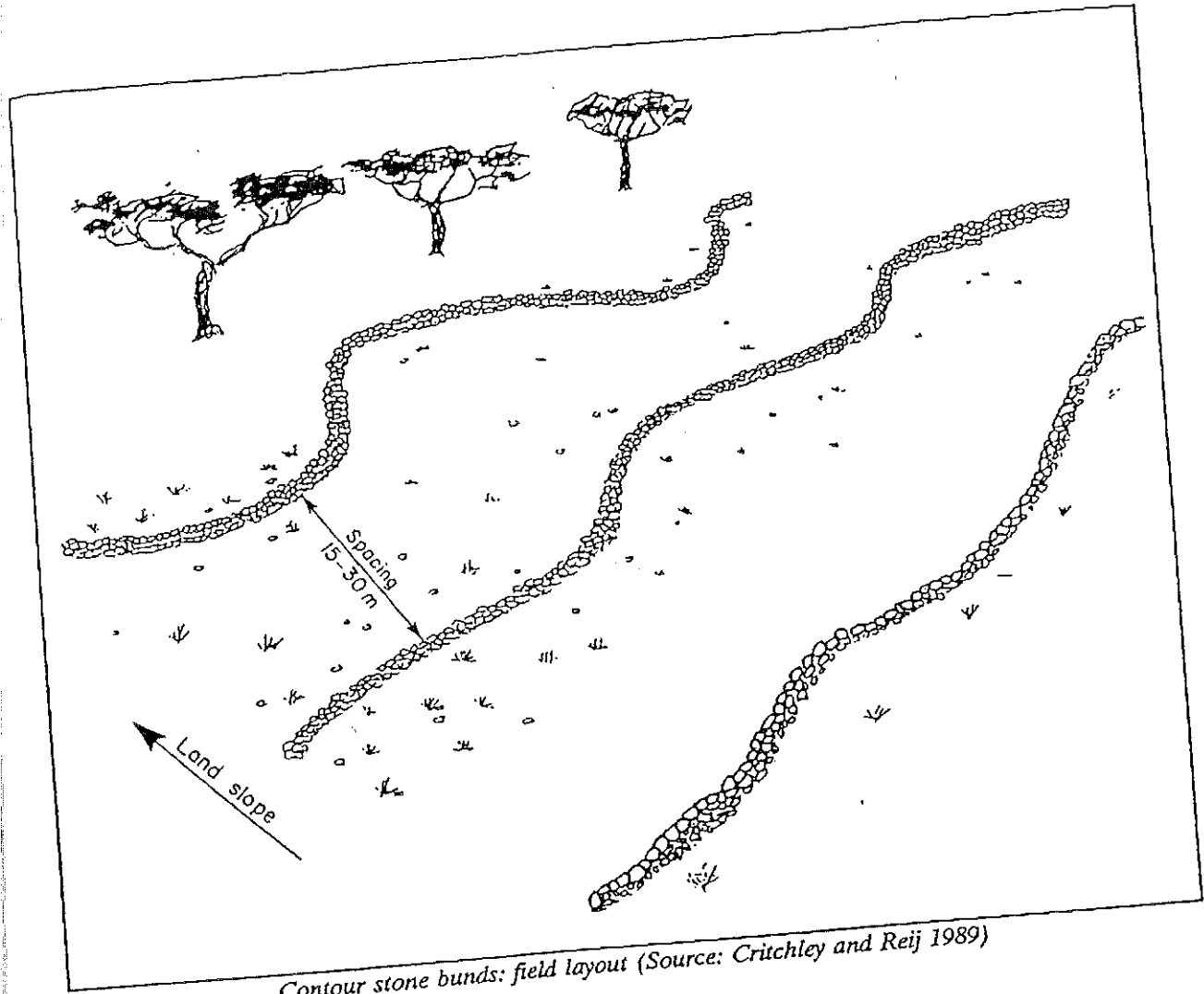
Stone bunds for crop production have been used effectively in the following conditions: rainfall of 200-750 mm per annum; in areas of good agricultural soils; and with slopes preferably less than 2 percent. It is also essential that there is a good supply of stone.

Spacing between lines of stones is normally between 15-30 m as indicated below. An initial minimum height of 25 cm is recommended with a base width of 35-40 cm. Improvements in filtering are achieved by placing the stone in a shallow trench of 5-10 cm depth. It is also important to incorporate both large and small stones in order to filter the water, as shown below. A table of quantities of stone and labour requirements is also given below.

Where stone is in short supply, grass and other vegetative material should be planted immediately behind the line in order over a period of time to develop a living barrier. Maintenance simply involves returning any dislodged stones after each rainstorm.



Contour stone bund: dimensions



Contour stone bunds: field layout (Source: Critchley and Reij 1989)

Permeable rock dams

This is a floodwater farming technique in which run-off water is spread across valley bottoms to improve crop production and developing gullies are 'healed' at the same time. The structures are typically long low rock dam walls across valleys. It is a labour intensive technique.

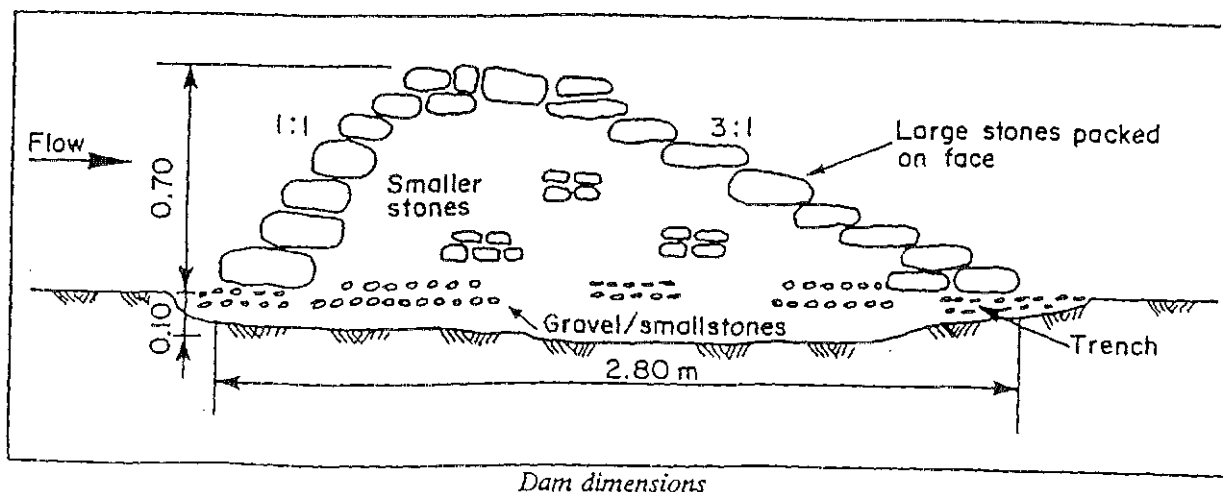
Permeable rock dams have been used for crop production under the following conditions: rainfall of 200-750 mm per annum; all agricultural soils; in wide, shallow valley beds and slopes of below 2 percent. Usually a series of dams are constructed across a valley bottom, therefore giving stability to a whole valley system.

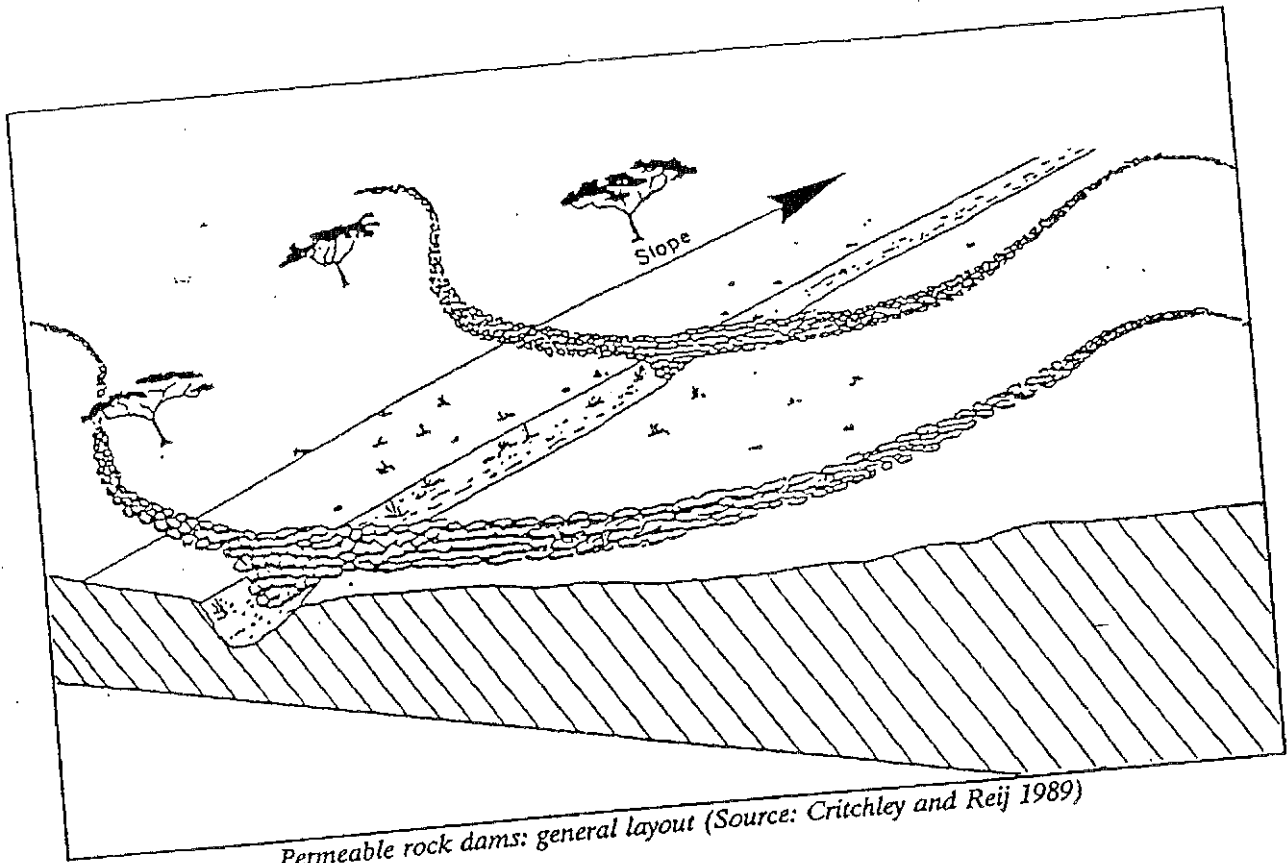
Dam design will vary from area to area, but in West Africa dam walls are usually between 0.7-1.5 m high and may extend up to a 1000 m across a valley floor. The amount of stone used on the largest structures can be anything up to 2000 tons. Attention needs also to be given to construction in order that smaller stones are packed in the centre of the dam which encourages the silting up of the dam and the retention of most of the run-off.

QUANTITIES FOR PERMEABLE ROCK DAMS

Land slope (%)	Spacing between dams* (m)	Volume of stone per ha cultivated (m ³)
0.5	140	70
1.0	70	140
1.5	47	208
2.0	35	280

* vertical intervals between adjacent dams = 0.7 m





Permeable rock dams: general layout (Source: Critchley and Reij 1989)

Water spreading bunds

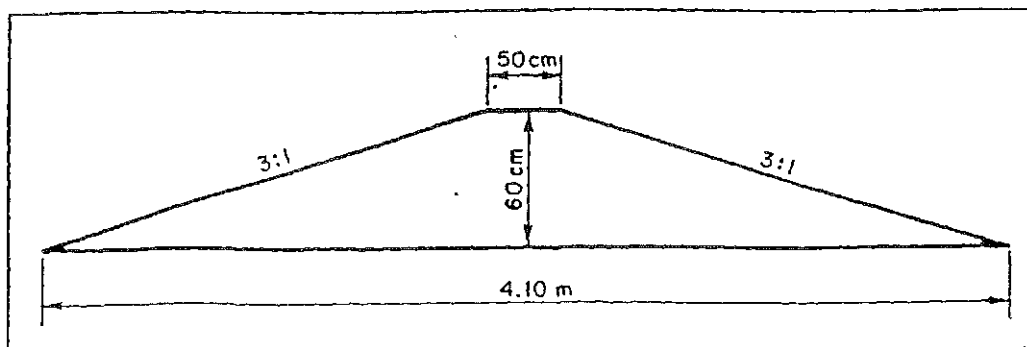
Water spreading bunds are used where run-off discharges are high (floodwater diverted from a watercourse) or where crops grown may be susceptible to waterlogging. As the name implies the main characteristic is that water is spread, rather than impounded.

Water spreading is a complex operation and there are relatively few examples of successful introduced schemes. In the Red Sea Province of Sudan, traditional water spreading schemes are being rehabilitated with some success. Large earthen embankments are constructed in the main or subsidiary channels and then spreading bunds to spread the diverted flow across an almost flat landscape. The spacing of these spreading bunds is up to 200 m with bunds as long as 150 m and a minimum of 75 cm in height.

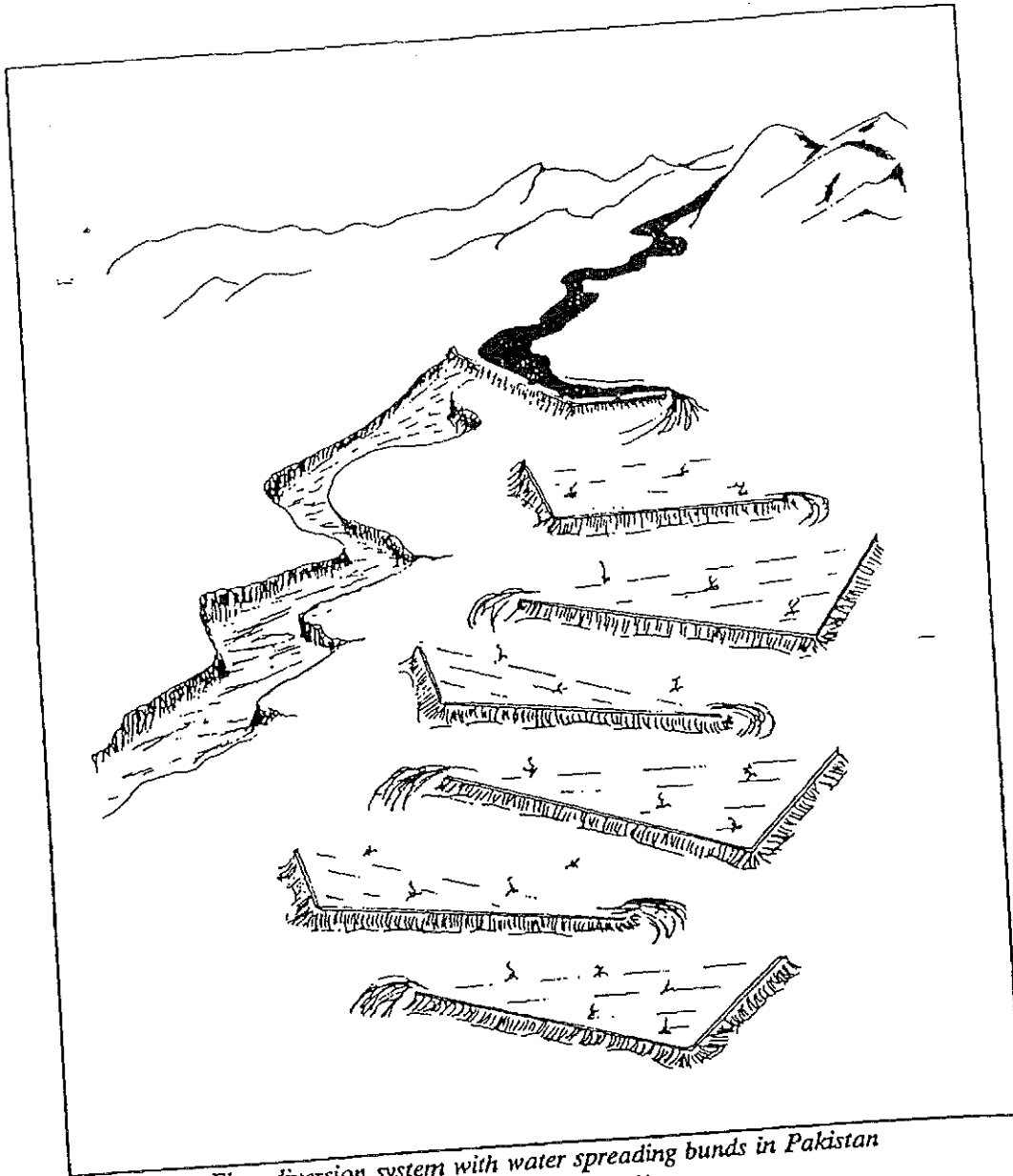
This is a labour intensive technique due to the relatively large amounts of earth which has to be moved.

QUANTITIES OF EARTHWORKS FOR
WATER SPREADING BUNDS

Slope class/ technique	No. bunds per ha	Total bund length (m)	Earthworks (m ³ /ha)
Level bunds - below 0.5%	2	200	275
Graded bunds - 0.5%	2	220	305
- 1.0%	3	330	455



Bund dimensions



*Flow diversion system with water spreading bunds in Pakistan
(Source: Nas 1980)*

APPENDIX 5 WATERPONDING BANKS : DESIGN, LAYOUT AND CONSTRUCTION

The material in this Appendix is taken from a 1987 article in the Journal of Soil Conservation, New South Wales, Australia, by D.W. Rhodes.

The success of waterponding appears to depend on three things:

- adequate bank construction
- efficient bank maintenance and
- good management of pastures allowing the establishment and
 persistence of native perennial species

Waterponds vary in shape from circular on flat land, to horseshoe on 0.15 percent slopes, and crescent shaped on 0.35 percent slopes. Banks are limited to 250 m length as the risk of breaching beyond this point increases. Each pond may contain up to 10 cm of ponded water, which reduces waterlogging and reduces the incidence of breaching. The distance between ponds is usually 10-15 m in order to allow an area for abstracting soil and vehicle passage between the ponds.

In Australia the use of catchment areas has been discontinued to permit the treatment of the maximum area possible. Similarly such ponds have proven more reliable and require less maintenance. Banks should be constructed so that the settled height of the earthen embankment is three times the height of water. Sharp curves in banks are avoided as these become pressure points as wave energy is channelled into such corners.

The current practice in Australia is to construct waterponds using a 115 kw road grader. In Mongolia this may not be appropriate and consideration should be given to the development of animal drawn graders as developed on the Indian sub-continent.

APPENDIX 6 CONSTRUCTION OF A RUN-OFF PLOT

Run-off plots are used to measure surface water run-off and should therefore be established directly in the project area.

The size of the plot should be as large as possible, since data obtained from small plots is rather misleading. The recommended minimum size of such plots is 4 m in width and 12 m length.

Siting of plots is important and care should be taken to avoid rills and gullies, unless these are typical of the whole area. Similarly, the gradients should reflect the project area. During construction every care must be taken to avoid disturbing the vegetation or compacting the soil. It may also be useful to construct several plots in the project area, in order to judge the respective character of different surfaces.

It is important that run-off from outside the plots is deflected by a cutoff drain sited above the plot. At the lower end of the plot the gutter should be installed in order to lead the run-off to a container, where it can later be measured. The gutter needs to have a gradient in order that water flows unimpeded into the collection tank. The soil around the gutter needs to be carefully backfilled and compacted.

The collection tank may be constructed from almost any water-tight materials (stone masonry or lined brick etc) but a single or series of 40 gallon drums will also meet the requirements. Tanks should be covered to avoid evaporation.

Following each storm the volume of water collected should be measured. Any silt should also be emptied. It is important also to site a rain-gauge beside each plot and in this way measure rainfall per storm.