Report on a Study Tour to Parts of Northeastern Sichuan, April 2000

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Introduction

As a result of the Central Government's "Western initiative" and as part of a major drive to reduce erosion in the Yangzi catchment, the Sichuan Forestry Department, through its Division of International Cooperation, invited us to participate in a study tour of potential land conservation project areas, during the early in April, 2000.

Background

The study areas lies wholly in the catchment of the Minjiang, a major tributary of the Yangzi. The Yangzi catchment contains some 20% of China's seriously eroded land, supplies about 56% of China's water and 60% of its sediments, though in Sichuan details of the actual sediment sources appear to be unknown. A series of major erosion control projects in catchments upstream of the Three Gorges Dam (due for completion in 2007) was begun in 1990. Their success, however, has been patchy, in part, if newspaper reports are reliable, because of widespread misappropriation of funds. In Sichuan, following the visit of Mr. Jiang Zemin in November 1999, an immediate initiative to prevent cultivation on slopes above 25° was begun with the objective of converting arable land to forest and pasture. The target is to take such land out of production after the autumn harvest, 2000.

Some of the consequences are likely to be as follows:

- reduction of "grain" supply by 49 kg per person.
- "temporary" ban on thinning or cutting branches in existing forests, leading to reduced availability of fuel wood.
- ban on commercial logging leading to increased poverty and reduced local government revenues.
- need for extensive food support (to be met by providing 150 kg rice per person "for as long as it takes", plus cash subsidies).
- severe difficulties in expanding afforestation and pasture development to ensure that land withdrawn from cultivation is put into new uses in a timely manner.
- sudden closure is likely to result in natural regeneration by low-quality species given that deforestation and cultivation are so extensive that natural seed reservoirs of desirable species scarcely exist. (While closure may achieve soil conservation of objectives, regeneration by low-quality species will raise costs of subsequent development of higher-quality species in afforestation and pasture development because of the need for clearance).

Landforms, Geology and Soils

Most of the area is very steep and broken with mountains inhabited up to about 2000m in elevation. Highest peaks are around 5000m. Valley tracts are narrow, mainly terraces of coarse to very coarse materials, in part appearing to be of fluvio-glacial origin.

The country rock is metamorphic, mainly schists of Upper Triassic age, but including quartzites with limestones (some dolomitic), shales and slate, all dipping at very high angles and tending to provide ready-made lines of weakness along which landslides, some very large, may occur. At higher elevations (Pleistocene?) block-fields occur. The areas is subject to earthquakes which are liable to trigger landslides.

A major superficial deposit is loess, highly variable in distribution and thickness but becoming more widespread and thicker towards Gansu in the north. (Roadside exposures showed depths varying from a few centimentres to five metres). Soils formed on loess are easily tilled with a good nutrient level, but, on slopes, these are readily eroded. They are excellent for agriculture and in some areas are excavated for use in the construction of *terre pisée* buildings.

Other than on loess, regardless of parent material, soils are shallow - 10-15cm - and low in organic matter. It seems possible, though no confirmation could be obtained, that on many slopes most readily erodible material has already gone. Most lower slopes are partially covered with coarse to very coarse colluvium, some grading into largely-eroded high-level remnants of alluvial (? fluvio-glacial) terraces. Much of this appears to be fairly stable, except where undercut by rivers, roads and paths. However, there are significant numbers of unstable scree slopes, some threatening lines of communication.

Climate and Water-supply

Climate is strongly monsoonal with warm but not particularly wet summers and cool dry winters, with snow lying at elevations above about 1900m. Both temperatures and rainfall are greatly influenced by location and elevation. The area lies in the lee of the Tibetan Plateau so that moisture-bearing south-westerlies are already comparatively dry. Air-masses descend and heat up leading to marked foehn effects. As a consequence aridity increases with lower elevation. Arid land is considered to be mainly below 2250m on sunny slopes and below 1800m on shady slopes.

In the Min valley at Maoxian the following have been recorded:

Av. Annual temperature		10°C
Absolute extremes	- max.	33°C
	- min.	11°C
Average annual rainfall		486 mm
Average annual evaporation		1306 mm
Sunshine		1543 hrs/yr
Days without frost		220
Days with snow		<50

At a lower elevation, Nanjiang county (500 - 1100 m elevation) the following were reported:

Av. Annual temperature	16.2°C
Average annual rainfall	1170 mm
Sunshine	1480 hrs/yr

Water-supply in the valleys is generally good but streams and rivers are mainly steep, rapid and to varying degrees their middle courses are entrenched below the prevailing alluvial

terrace levels. The main stream of the Min R. is diverted at several points for run-of-the-river hydro generation, as are several tributaries tapped for "mini-hydros". None has storage. No irrigation was observed other than limited pump irrigation for the re-establishment of trees at a number of points.

Agricultural Land Use

Valley-floor alluvium is generally intensively used with substantial inputs of compost, pig and human waste. At lower levels rape-seed in winter alternates with maize in summer. At higher levels, e.g. N of Wenchuan, it is generally too cold for winter and the main summer crops are maize and *Solanum* potatoes. A range of green vegetables is also grown. On slopes the same crops, sometimes including vegetables, are grown with orchards of apples, prickly ash and less commonly walnuts, peaches, apricots, plums, loquat, ginko, pears, cherries. Orchards also occupy some flat terraced lands with intercropped rape-seed or the fodder legume vetch (*Vicia sativa*).

Many families own a pig or two, usually buying weaners and selling them for cash. Pigs play an important role in the conversion of agricultural wastes into manure. They are kept in simple sties - basically a stone-lined hole in the ground with a rough timber cover.

Red cattle, two to a plough, are the major source of traction, though hand-tillage is common. Though the visit coincided with the "skinny season" the animals seen appeared to be in good condition. They are herded, mainly as pairs, on stubble, road and river sides and on uncultivated slopes. Nowhere was "cut-and-carry" pasture production observed. Nor was any dairy production.

Goats, both black and white, were observed in a number of places, in flocks of half up to two dozen, grazing uncultivated slopes under supervision.

Maize leaves and stems, leaves from fruit trees form a proportion of the fodder. Small branches of poplar (*Populus* spp.) are also sometimes cut for feed. At Wenchuan and elsewhere vetch, "black wheat grass" (not identified) and a shrub, "*shada wang*" (not identified) are being grown as fodder. However, animals very generally are forced to "get a bite" wherever they can. Fodder quality is thus likely to be low.

Soil Erosion

Little information was forthcoming on the actual sources of sediment being delivered to rivers, not even gross estimates. Data from other regions, however, suggest that on unprotected tilled slopes, levels of sediment generation are four, occasionally five times higher than on slopes with any kind of closed vegetation. In this connection it is interesting to note that work in Guangdong *Cunninghamina* plantations indicates sediment generation on order of magnitude higher than under low closed vegetation.

But the movement of sediment on slopes and its delivery to streams are quite distinct and it should not be assumed that all sediment generated on slopes necessarily finds its way into watercourses, especially in the short term. One elderly farmer at Caopo, working a large loessal patch, noted the loss of 0.5m of soil in very heavy rain in 1977. Under very high intensities, it can probably be assumed that much sediment generated in fact reaches the drainage but at other times it may not.

It should also be accepted that natural levels of erosion in the terrain will always be high, especially as all watercourses vigorously undercut their banks. It is also clear that considerable storage of material occurs as point-bars and bank-side deposits. This will readily be mobilized at high discharges, especially in the general absence of bankside vegetation. In this area it will be important to establish, at least broadly, the main sources of sediments delivered, for only thus may appropriate remedial strategies be formulated. For instance, on many slopes the soils are so thin and the residual materials are so coarse that little erodible material remains. It is also a general principle in erosion that a large proportion of material may be derived from relatively limited areas. A prime candidate for this must be patches of loess. Another is active scree. Screes slopes are common along most watercourses and all transportation routes. So far as was observed, no remediation is currently undertaken.

Soil Conservation

In the province generally - and expectably - soil conservation practice is extremely uneven from place to place. In the northeast the main activity is tree-planting, as seen in the vicinity of Maoxian. The main species used are pines - *Pinus massoniana, P. yunnanensis* with a little *P. radiata* grown from New Zealand seed - "Chinese fir", (*Cunninghamia lanceolata*), *Cupressus* spp. *Populus* sp., "red birch" and maple (species not determined).

We were, unfortunately, not able to observe plantations at close hand but virtually all field planting is done in pits with a little, as at Chibusu, Maoxian county, on terraces. (It was not clear whether these had been cut for the purpose or were old cultivation terraces, probably the latter). Consequently it was not possible to assess the degree to which a good depth and coverage by litter had been achieved or to assess the degree to which erosion was continuing under closed canopies, where these had formed. Most plantings were, in fact, very recent, except near Maoxian town.

Little evidence was seen of other forms of conservation other than a few stone-faced sloping terraces and a fair number of flat stone-faced terraces especially on land of lower elevation and in the vicinity of villages. No active terrace construction was seen and the approach is, in any case, a relatively expensive one though stone is readily available. Contour ploughing is extremely rare. One informant at Caopo suggested that were maize to be planted in contour ridges it would die as a result of drying winds that blow parallel to the axis of the valley. He spoke of the danger of washouts if a contour ridge were to fail in heavy rain. These views deserve respect and the trial of alternatives, though the imminence of land conversion will not permit this at this location. (It should also be noted that contour ploughing with animals is more difficult than upslope-downslope.)

Cover-crops, mainly vetch of recent establishment, were observed but rarely. Terrace-edge or lower field boundary plantings for erosion control are entirely absent.

Given the high risk of bank-side erosion, plantings along watercourses are notably rare, only a few short stretches of *Populus* being observed. (Reliance for protection has been mainly concrete walling, much of it irreparably damaged). A good deal of the immediate margin of the main Gansu highway has been planted, mainly with black locust (*Robinia pseudoacacia*) as an erosion control measure. Its effectiveness is questionable as a ground cover is largely absent. (There may also be a problem of damage by passing vehicles as trees mature. Some

attention could also be given to the possible creation of a winter-time ice hazard on the road as result of shading).

There is obvious scope for improvement in soil conservation although, as mentioned previously, a cost-effective overall strategy cannot be developed until sediment sources are adequately identified. This does not mean that small-scale, local initiatives cannot proceed.

Trees and Erosion Control

At this point a number of basic points need to be addressed.

The impression was gained that Forestry Department staff equate soil conservation with afforestation. Given their training it would be most understandable if this really were the case. However, it is a fundamental principle that the rate of sediment generation slopes does not begin to fall unless and until not only the new forest canopy closes but also there is a good ground cover, whether of litter or adventitious plants. Drip, stem-flow and overland flow may persist in quite mature plantations, especially as the trees are even-aged. The canopy in such plantations tends to close early and this may tend to suppress the ground cover and to delay the effective control of sediment movement. *Eucalyptus* spp. and *Cunninghamia*, where planted at the usual densities, are quite notorious is thus suppressing ground cover.

The primary objective in erosion control is to slow the removal of sediment as quickly and effectively as possible. There are several ways of achieving this, other than by creating "dead" barriers such as walls or erosion trenches, both of which tend to be readily over-topped by accumulating sediments.

Close area to cropping grazing, fuel collection. This assumes rapid natural regeneration. We saw only one example of this, atypically on terraces at Chibusu, Maoxian. Here natural regeneration was excellent, so much so that naturally-regenerated "rubbish plants" - nevertheless an effective cover - were seriously competing with planted timber species. This procedure also assumes that villagers will have alternative sources of grazing, fuel and food.

Plant improved grasses, legumes or both. Were it possible to sow cropland directly after the last harvest, this would be a cost-effective approach. However, once naturally-regenerated plants become established it become more and more difficult for improved grasses and legumes to complete with the "volunteer" weedy vegetation. There is also the question of what to sow. Vetch clearly succeeds but along with grasses such as cocksfoot (*Dactylis glomerata*), Yorkshire fog (*Holcus lanatus*) and most legumes - the clovers (*Trifolium* spp.), lotus (*Lotus pedunculatus*) need to be sown into prepared soil. In principle, a cheaper approach, once weedy vegetation has come in, would be oversowing, the approach widely used on New Zealand hill pastures. So far as we know this has not be tried in the area but remains a long-term alternative aimed at improved fodder supply, whether for 'cut-and-carry" to stall-fed animals or direct grazing. (The former is to be preferred as it a simplifies management and makes manure available for more intensive forms of cultivation). In practice, however, there is a large question-mark concerning the efficacy of over-sowing in the context of S.W. China.

Plant contour hedges to trap moving sediment, improve water retention. This has nowhere been attempted in northwest Sichuan, so far as is known. In lower, warmer parts of southern China, Vetiver grass (*Vetiveria zinzanioides*) is increasingly being used for this purpose, as

are the leguminous shrubs *Coronilla* and *Tephrosia*. All are effective, especially Vetiver. They also provide fodder and fuel. However, northeast Sichuan is probably too cold for these essentially tropical plants. Alternatives may include some of the low-growing bamboos or pampas grass (*Cortaderia selloana*). This approach does not require the cessation of tillage even on steep slopes. However, like oversowing, it is untested in northeastern Sichuan.

Plant trees to reduce river-bank scouring. Here low rainfall is not a limitation. Planting willow poles (*Salix* spp.) is a well-established and effective method. Once-established *Salix* provides protection during all but the highest floods. Replacement of damaged plantings is essential as scour will quickly attack unprotected sections of river-bank. Leaves and small branches are good fodder ad some harvesting for fuel is not deleterious to growth as the main function - consolidation of the banks by the growth of a root mat - is not impaired.

Plant trees to control movement of screen and debris slides. While *Salix* has been used for this purpose, species of elder, especially *Alnus nepalensis*, is provenly effective, especially as an initial stabilizing species which can then be followed by other more-demanding species. In northwestern Sichuan the local birch (*Betula* spp.) would be worth a trial to follow stabilization. There is some urgency to control scree and moving debris along paths and tracks, including many recently constructed for access to power pylons. These are obviously generating significant sediment, as yet entirely without control. Sites are localized and easily accessible by wheeled vehicles, unlike most of the tilled areas.

Afforestation Generally

While afforestation may ultimately control erosion, it suffers a number of technical and economic problems. At the technical level is the problem of raising and planting a sufficiently large number of provenly-effective species in the short time span demanded by the new Land Conversion policy. Land for nurseries is limited and they suffer losses from wild animals. A useful control here would be the use of standard two-strand electric fences driven by solar panels. Their use could also be extended to planted areas where rodents and deer also are a problem, leading to low survival rates. Lack of water is a major problem, currently being met, very expensively, by pump irrigation over long distances and to great heights. However, even with 400 mm annual rainfall it should be possible to identify and to trial arid-region species such as the tamarisk (fam: Tamaricaceae) to act as a "nurse-crop" for other more-demanding species, preferably natives. (Experience elsewhere suggests that on very difficult degraded sites there may well be no effective native species. In this case using an exotic "nurse-crop" is essential to success). It is recognized that there is always a risk that exotics may become a pest but in the absence of any trees at all this may have to be accepted.

Is long-term natural regeneration an option? It may be on recently logged sites and near existing stands of forest which can act as seed reservoirs. But, as remarked earlier, deforestation has been so extensive that in most areas reservoirs of the seed of desirable forest species no longer exist. Closing areas to grazing, fuel collection and tillage will unquestionably lead to natural regeneration of a kind and expectably to a closed vegetation cover. But that would be to incur a significant opportunity cost for there is no reason to envisage the permanent closure of land, except perhaps on high erosion-risk land such as currently-mobile scree. For most land the objective presumably is the establishment of viable commercial forest which, if logged carefully will always offer adequate protection against erosion.

However, people cannot eat trees so the question of long-term viability of cropping remains, especially as farmers have an understandable desire to secure for themselves a substantial portion of their own food supply. This leads to the question of agroforestry and especially to the role of continued arable farming within it.

Agroforestry

There is clearly a considerable body of literature on this subject in Sichuan. Since this is mostly in Chinese it is, unfortunately, inaccessible to us. Discussions in the field helped to clarify our understanding but we are still not clear if our concept of agroforestry, which includes the growing of trees with pasture or with arable cropping in the same field, is shared by Sichuan colleagues. To be sure we were shown fruit trees intercropped with vetch as an example but it was the only one. Nowhere did we see timber trees with pasture or arable crops with hedgerows.

Insofar as "agroforestry" is developed in those areas of northeastern Sichuan we visited, the main focus is on fruit and nut trees, with some "prickly ash" (*Fraxinus*?) grown for sale as a condiment. (A list is given earlier). Production is almost entirely commerically-oriented with very minor use of prunings as fuel and fodder. Apples are by far the most common tree-crop, grown both with and without a ground crop of vetch or, at lower elevations, rape-seed. Apple-growing is being substantially promoted, somewhat surprisingly given very low farm-gate prices - 20 *fen*/kg at a high-level village in northern Maoxian, 80 *fen*/kg at Shan Guan Miao, Wenchuan. (As it was early spring, no assessment of quantity or quality of produce was possible but generally, at retail, quality is well below international standards, a consequence of inadequate grading, storage and transportation, refrigeration being absent. Taste and texture are also inferior. Spotted fruit are common).

The prices of other fruits are rather better, with cherries fetching up to ¥30 per kilogram at the retail level. However, production is necessarily highly seasonal. As far as is known refrigerated storage at wholesale and retail levels does not exist so the "selling season" coincides with harvest, leading to strong supply for short periods and depressed prices. However, there is likely to be some unsatisfied demand on the Chengdu market. It is to be particularly emphasized that the promotion of fruit production without a corresponding development of marketing is likely to be on exercise in futility.

Agroforestry may also be developed as a means of enhancing production and of soil conservation in croplands. There can be little doubt that tilled slopes of less than 25° angle are important generators of sediments. (It is also doubtful that conversion from arable cropland to pasture and forest will everywhere be successfully enforced). While circumstances will vary from site to site it nevertheless seems worthwhile developing appropriate agroforestry models for use at the village level. Some key issues are highlighted.

Tillage. Current up-slope, downslope tillage provides ready-made channels for concentrated water-flow and the development of rills. (No such rills were actually observed during our visit as it was the season of spring tillage which would have ploughed them out). In contrast to Guizhou province, where about a fifth of the cultivated land is tilled on the contour, in northeastern Sichuan it is rare. This may well be because as one farmer observed, contour ridging causes agronomic problems where drying winds blow along the valleys. If this be correct then a possible solution is the growing of shelter belts normal to the slope, combined with contour tillage and lower field boundary erosion-control hedges. However, great care

would need to be exercised in the choice of species for such shelter. They could be trees, shrubs or tall grasses. Ideally they would be multipurpose, providing fuel and fodder but not significantly affecting crops grown nearby. Crowns would be narrow, so as to reduce shading effects and the roots non-ramifying, to reduce competition with the crop for water and nutrients. Such shelter should not provide a habitat for rodents and other pests. Fields would thus become a series of cells, with shelter-belts planted normal to the slope on two sides and erosion-control hedges on the contour. Appropriate species for such plantings remain to be identified. Pampas grass may be suitable though it requires severe trimming to keep it in reasonable bounds. (Without trimming a hedge one metre wide will quickly become three metres wide). Some of the Cupressccеae and cedars (*Cedrus* spp.) meet these specifications as does the Lombardy paplar (*Populus nigra*) the last having the advantage that it is usable as fodder and fuel as well as withstanding trimming well.

Pasture. Apart from small areas of vetch under apples, no improved pastures were observed, the existing small flocks of goats and pairs of cattle grazing whenever they can. Given the speed at which conversion from cropland to pasture in supposed to take place it seems unlikely that more than a tiny fraction of the current cropland can be converted directly into improved pastures. Rather, the common approach will be either to allow natural regeneration to occur or to plant trees and then develop pastures. Pasture development will be a very new area for foresters who were understandably vague as to how such pastures might be developed and what their components might be.

However, on the basis of observations in upland Guizhou (Weining *hsien*, 2000m) it is possible to be fairly firm as to what should not be tried. There an attempt was made to establish high-quality rye grass and clover pasture. After tillage and fertilizer application these were sown but initial results were disappointing. Further tillage and resowing was undertaken with better results but the persistence of these components has been poor. Such a high-input/high output system is not to be encouraged. Costs of lime fertilizer, fencing etc. are uneconomically high, especially where road access, as to most upland villages in Sichuan, is lacking.

The foregoing is not a reason for not attempting pasture improvement but the approach must involve a low level of technical inputs to be sustainable. As mentioned earlier an approach using such hardy grasses as cocksfoot, Yorkshire fog and legumes such as *Lotus pedunculatus* and the hardier, more persistent clovers such as *Trifolium subterraneum* is worth trial. So may non-toxic strains of *Lupinus*. In this connection it is worth noting that Sichuan soils may not contain adequate numbers or species of N-fixing micro-organisms to ensure satisfactory nodulation in legumes.

Rhizobium or similar inoculation of seed should be routine. An alternative approach may be the cultivation of tree or shrub fodders. So far as we have been able to determine, virtually no research on the possible utility of local species has been done in south or southwest China. However, the "black locust" (*Robinia pseudoacacia*) already being planted as a roadside tree, provides fodder of fair to moderate quality as well as fuel.

Wood fuel, in fact, is difficult to acquire in some villages. Since the average family consumes a minimum about three kilograms of fuel per day just for cooking their own food, the potential removals for this purpose are considerable. In addition, pig feed also requires cooking. Both are currently done on "tiger stoves" of traditional design. Such stoves have very low thermal efficiency, about eight per cent. Coal stoves of a more efficient design are known but coal availability is limited and costs cash, whereas wood and grass are free for the

cost of collecting them. In Guangdong an improved design of wood/grass fuelled stone with a thermal efficiency of around 30 per cent has been developed and is now widespread in the village as households were provided with a subsidy to build them. In this connection it is worth mentioning biogas generation as a means of reducing the demand for wood fuel. The technology is fairly simple and the gas can be used both for heating and lighting. The capital cost, however, is between 10 and 20 times higher than for improved wood-burning stones. But the most serious problem is that biogas digestors reduce by about two-thirds the quantity of nutrients input in the animal and human waste they consume, a fact often suppressed by their proponents. Unless there is a nutrient surplus in the farm system, biogas is highly inadvisable although unexceptionable if the nutrients consumed in producing it can be made good from other sources, such as purchased fertilizer. (In fact, it may be more economic to move to kerosene for cooking and to retain wastes as agricultural fertilizer. A kerosene stove costs much less than a biogas digestor.)