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Chapter 7

Soil Conservation Research and Training Requirements in Developing Tropical Countries[1]

N. W. HUDSON[2]

INTRODUCTION

In the developing countries of the tropics, soil erosion is reducing productivity at an alarming rate. In most of these countries, attempts to reduce or control the erosion are hopelessly inadequate. The most immediate requirement is a greatly increased program of training so that presently available knowledge can be put to use in the field. The second requirement is an increased and coordinated research program to seek information which is not presently available on the particular problems of the developing countries in the tropics. This paper discusses the research needs and the present research capacity, and then the training needs and existing capacity.

THE DIFFERENT SITUATION IN THE TROPICS

The paper by Foster et al. (1979) discusses the extent to which it is possible to transfer to tropical countries the knowledge and expertise which has been obtained in the USA as a result of vast experience in con-

[1]Paper presented at the Symp. on Soil Erosion and Conservation in the Tropics, Div. A-6, ASA annual meeting, Fort Collins, Colo., August 1979.

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servation research and its application. The author's view is that the knowledge and understanding of the principles of soil erosion and erosion control are applicable worldwide. Also the techniques, such as how to design rainfall simulators and how to build gully control drop structures, are transferable. However, when it comes to applying soil conservation measures, the conditions are so fundamentally different that no amount of extrapolation can make the developed country experience relevant to a developing country in the tropics.

It is worth reviewing the conditions under which soil conservation is carried out in these two situations.

In North America we have the following:

1. The agricultural industry is highly developed and highly mechanized;
2. The agricultural community is well educated and well informed;
3. They are supported by first-class research effort and good extension services;
4. The population pressure on the land and the need to use it intensively are both comparatively light;
5. Credit and financial support are readily available;
6. Individual land holdings are large enough so that conservation plans can be applied; and
7. The topography is, on the whole, fairly gentle.

The Land Capability Classification and the Universal Soil Loss Equation (USLE) have been developed for this situation.

By contrast, in the developing tropical countries, every one of these conditions is reversed. Farming is undeveloped; the farmers are short of education, advice, expertise, and capital. There is very severe pressure and all the support services are either absent or much less generous. The erosion hazard is increased by erosive rainfall and severe topography. Furthermore, there may be social constraints which inhibit sound land use. For example, in many countries, there is the cultural ethic that everybody has the right to own his own land; a proposition which is becoming untenable as the population increases. Another pressure comes with hereditary fragmentation of landholdings. This must inevitably lead to more people on smaller holdings; and eventually the point comes where rational, long-term land use is not possible.

In fact, soil conservation for the peasant farmer, in Java for example, is a completely different game which has a different set of rules. The most significant difference is that in North America or Europe it is possible to reduce erosion to the point where the land can be used indefinitely, or at least for a long time. The questions are: What combination of conservation measures to use? What level of erosion is tolerable? and What is the cost?

Erosion control in the tropics must start with the realization that in most cases there can be no technical solution to the problem. Farmers will continue to grow food crops on 100% slopes because they have no choice; what we have to look for is practical and acceptable ways of reducing the erosion as much as possible. The option of changing the land use is not open, at least not without massive social, political, and economic change.

Physical measures, such as bench terracing, cannot be justified when the cash value of the produce is a fraction of the cost of constructing the terraces.

To summarize this theme, we are operating so far outside the range of our experiments that we cannot extrapolate.

RESEARCH NEEDS

The author suggests two main research requirements. There is a need for detailed information on the variables which influence the amount of erosion such as rain, soil, topography, land use, and crop management, but equally important is the need for a model into which these component pieces of information can be directed.

TROPICAL RAINFALL EROSION

The difference between the erosive power of tropical rainfall and temperate rainfall is well documented. Tropical rainfall can be greater in amount and at higher intensities and the distribution patterns are likely to be different. It is, therefore, not surprising that empirical measures of erosivity derived in different situations have not been very satisfactory when applied in the tropics (Hudson, 1976; Morgan, 1979). Changes in the method of calculating EI_{30} (Wischmeier and Smith, 1978) will go some way towards reducing the inconsistencies which have arisen when applying this method to tropical rainfall. What is more significant is that the change in the method means that the attempts to extrapolate this index of erosivity to tropical rain in the last 15 years were a waste of time. Many studies in many countries have tested the relevance of EI_{30} in the tropics; for example, Roose (1977) in Ivory Coast, Hudson (1976) in Rhodesia, Morgan (1979) in Malaysia, Aina et al. (1977) in Nigeria, Bols (1978) in Java, and Gupta and Babu (1967) in India. These researchers could go back to their data and recalculate correlation coefficients, but this would not be sensible. A sound rule of experimental science is that one should never extrapolate an empirical relationship beyond the measured range, and we should stop trying to extend EI_{30} into conditions different from those in which it was derived.

The emphasis should be changed from seeking empirical relationships to the search for a causative relationship between erosion and the parameters of tropical rainfall. For example, it is possible that, since in the tropics there may be more rainfall at higher intensity on steeper land with poor crop cover, the effect of the runoff component may be significantly greater than in the North American situation. There is no justification for assuming that a single parameter based on energy is the best starting point for the model of erosivity.

TROPICAL SOILS

Major differences between temperate and tropical soils clearly exist. Their relative resistance to the erosion process is less clearly established. This may be partly the consequence of the wide variation in the nature of

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the erosion process in the tropics. The USLE K values are derived in a situation where there is some degree of consistency in the combination of the splash erosion process (detachability) and the surface flow effect (transportability). In the tropics, the range is much wider. There is the situation of a light noncohesive soil of very high infiltration capacity where there is no surface flow but large erosion losses due entirely to splash from high energy rainfall (for example the volcanic ash soils of Central Java). Equally, there are cases where the large volumes of rainfall result in high rates of surface flow which become a powerful erosive agent.

The author suggests it is unlikely that any one single measure of erodibility will account for the separate properties of resistance to splash and resistance to surface flow. The point made earlier about empirical indices of erosivity applies equally to empirical models of erodibility. The Wischmeier nomograph (Wischmeier et al., 1971) is derived from data on American soils and can be expected to work in the USA; but we should neither assume nor expect that it will be equally valid for different soils in the humid tropics or in arid regions; and, indeed, attempts to extrapolate it to these conditions have, on the whole, been disappointing (Choudry, 1973). The first priority would seem to be basic research on the fundamentals of erodibility. In particular, can resistance to detachment and resistance to surface flow be separately assessed and then combined?

EFFECTS OF TOPOGRAPHY

The effects of steepness (S) and length (L) of slope have been thoroughly investigated in the USA; but the evidence which might justify extrapolating the accepted relationships into the conditions frequently encountered in the tropics is inadequate. Wischmeier (1976) has pointed out that errors due to extrapolation are particularly hazardous in the case of factors L and S.

Mutchler (1080) and Barnett et al. (1978) have shown that on flatlands with slopes less than 3%, the L and S relationships can be significantly different. In the tropics, we are usually more concerned with the other end of the range. The USLE data goes up to a maximum of 18% but the vast majority of the data is at lesser slopes. The author believes that there is very little justification for extrapolating data up to 50% as is done in the recent Agric. Handb. 537 (Wischmeier and Smith, 1978).

Some of the most serious erosion situations in the tropics are on slopes between 50 and 100%, with field lengths of up to 100 m, but no examples of experimental studies of this situation have been found.

APPROPRIATE LAND USE

The conventional approach to land selection and land use is that the first principle of rational soil conservation and management is to make appropriate use of the available land; i.e., to match the use of the land to the physical and ecological conditions. It may be possible to ease limitations caused by waterlogging if we drain the land, or the risk of erosion can be reduced by applying conservation methods, but there are limits to

the modifications which can be made. If land is inherently unsuitable for arable use, it is better to use it for some other purpose rather than to try to change the limitations.

That is the conventional approach; and, of course, it is theoretically and scientifically the right one. The reality of the developing world in the tropics is quite different. Where every hectare of land is producing food for a hungry family, it is not constructive to point out that ecologically the land should be under forest.

We should attempt to apply the kind of correlation between land classification and land use which is ably demonstrated in the paper by Sheng (1979). This is no longer experimental theory. It is a valid solution to a problem outside the range of the Land Capability Classification. However, whether the cause is economic, social, cultural, or political, there are throughout the tropics large areas of land which are going to be used unsuitably in the foreseeable future. There is an urgent need for research on this problem, but the approach must cover a much wider front than the technical aspects.

CONSERVATION PRACTICES

American research and practical experience have generated a vast experience of conservation practices. These are very well documented and, on the whole, understood and applied where they are appropriate in the tropics. But there are two large gaps which are not covered and where more research is required.

The first need is for information on physical conservation measures on land steeper than 20%. There have been some interesting field trials during FAO projects by Sheng (1975) in Jamaica and El Salvador and Thailand, and by John and van der Goot (1976) in Java on bench terracing and hillside ditches. However, our knowledge and experience is less than adequate, particularly on the difficult question of how to get the surface runoff down terraced steep slopes without expensive structures.

The second and equally pressing research need is on the reduction of erosion by crop management alone in situations where no physical conservation works are possible. Two situations illustrate this point. In El Salvador and Java, peasant farmers farm holdings of 1 or 2 ha with insecure tenancy and no possibility of constructing bench terraces or hillside ditches. The question is how much can erosion be reduced on 50 and 60% slopes by contour planting, mulching, multiple cropping, and other agronomic techniques. The other situation is the vast gently sloping plains of Central India. There, physical measures are impractical for two reasons. The pattern of fragmented land ownership makes it impossible to design the terraces and waterways required for a sensible water disposal system and anyway the cost is beyond the resources of the farmers and the Government. Again the need is for research into what can be done by improved agronomic practices which are both practical and acceptable to the farmers. The research programs at ICRISAT, and the Indo-UK project at Indore (Shaxson, 1980) provide a good starting point.

Table 1. A list of research and training programs in soil conservation in the tropics.†

Central and South America:	
Venezuela	1. Faculty of Agronomy, Central Univ. of Venezuela, Maracay‡
	2. Interamerican Center for Soil and Water Management Studies (CIDIAT), Merida
Peru	University of La Molina
Brazil	University of Sao Paulo
El Salvador	Soil Conservation Service, Directorate of Renewable Natural Resources, Ministry of Agriculture
Jamaica	Department of Soil Conservation
Puerto Rico	Agricultural Exp. Stn., USDA-SEA, Rio Piedras
Colombia	1. Coffee Research Station, Chinchina
	2. International Center for Tropical Agriculture (CIAT), Cali
Mexico	University of Chapingo
Surinam	Outreach program of Agricultural Univ., Wageningen, Netherlands§
Asia and Pacific:	
Hawaii	Department of Agronomy and Soil Science, Univ. of Hawaii at Manoa
Malaysia	1. Faculty of Agricultural Engineering, Agricultural Univ. of Malaysia, Serdang
	2. Soil Survey Division, Dep. of Agriculture, Kuching, Sarawak
	3. Malaysian Agricultural Research and Development Institute (MARDI), Serdang
Indonesia:	
Java	1. Faculty of Forestry, Agricultural Univ. of Bogor
	2. Soils Research Institute, Bogor
	3. Institute of Ecology, Bandung (in association with Dep. of Sylviculture, Agricultural Univ., Wageningen, Netherlands
	4. Upper Solo Watershed Management Project, Directorate of Reforestation, Dep. of Agriculture
	5. Brabiyaya University, Malang (in association with Agricultural Univ., Wageningen, Netherlands)
	6. Gajah Mada Univ., Jogjakarta (in association with ITC, Univ. of Amsterdam and Vrije University, Netherlands)
	7. Outreach training program, Univ. of Melbourne
India	1. Soil Conservation Division, Ministry of Agriculture and Irrigation
	2. Indo-UK Project, College of Agriculture, Indore
	3. Central Soil and Water Conservation Research and Training Institute, Dehra Dun
	4. Land and Water Management Farming Systems Research Program, International Crops Research Institute (ICRISAT), Hyderabad
	5. Central Arid Zone Research Institute, Jodhpur
Sri Lanka	1. Land and Water Use Division, Dep. of Agriculture, Peradeniya
	2. Tea Research Institute, Talawakele
	3. Rubber Research Institute, Agalawatta
	4. Coconut Research Institute, Lunuwilla
	5. Department of Agricultural Engineering, University of Sri Lanka, Peradeniya
	6. Department of Agriculture (outreach training program of the National College of Agricultural Engineering, England)
Thailand	1. Soil and Water Conservation Section, Land Development Dep., Ministry of Agriculture and Cooperation
	2. Division of Agricultural and Food Engineering, Asian Institute of Technology, Bangkok
	3. FAO Integrated Watershed Project, Chiang Mai
	4. Thai-Australian Project, Chiang Mai

(continued on next page)

Table 1. Continued.

Indonesia:	
Australia	1. Land Conservation Unit, Winnellie, Darwin N.T.
	2. Soils Division, CISRO, Canberra
	3. Soil Conservation Service of New South Wales
	4. Faculty of Resource Management, Univ. of New England, Armidale, New South Wales
	5. Department of Civil Engineering, Univ. of Melbourne
	6. School of Earth Sciences, Macquarie Univ., New South Wales
Africa:	
Nigeria	1. Department of Soil Science, Univ. of Nigeria, Nsukka
	2. Geography Dep., Univ. of Nigeria, Nsukka
	3. Farming Systems Dep., International Institute for Tropical Agriculture (IITA). Also in association with Graduate School of Geography, Clark University, Worcester, Mass., USA
Ivory Coast	1. French Office for Research Overseas (ORSTROM), Laboratory of Applied Geology, Univ. of Orleans, France
	2. Outreach teaching program of Dep. of Soil Science and Geology, Agricultural Univ., Wageningen, Netherlands
Ghana	Soil Research Institute, Kumasi
Tanzania	Outreach program of Dep. of Physical Geography, Univ. of Uppsala, Sweden
Kenya	1. Outreach teaching program of Dep. of Soil Science and Geology, Agricultural Univ., Wageningen, Netherlands
	2. Faculty of Agricultural Engineering, Univ. of Nairobi
Morocco	1. SOGREAH, Grenoble, France
	2. Outreach research program of Univ. of Amsterdam, Netherlands
Ethiopia	Geographical Institute, Univ. of Bern, Switzerland.

† It is certain that there will be many other programs not included in this list. The author would welcome information on them.

‡ Some of the programs listed are concerned primarily with training, others primarily with research, but these have not been indicated because most programs contain an element of both.

§ There are many universities and institutes in Europe and North America carrying out research on soil conservation in the tropics or training students from tropical countries. These are only listed where there is an outreach program located in the tropics.

RESEARCH CAPACITY

A list of known research projects on soil conservation in the tropics is given in Table 1. It is impressive in its size and geographical coverage. However, many of the projects are very limited in size and scope. Even the international research institutes like ICRISAT and IITA only have a handful of graduate research workers on soil erosion within a Farming Systems Division. In other cases, a lone university teacher or research officer in a government department is trying to carry out a research program with little local support and no contact with researchers in other countries.

It could be argued that the problem of erosion is so important that it deserves the formation of an international center on the lines of the international crop research institutes IRRI, CIMMYT, and CIP. However, there are two counter arguments. First, that erosion control is site-specific and so should be dispersed rather than centralized. Second, that soil con-

Table 2. A schedule of training needs.

Title	Typical participant	Training requirements	Typical course structure a. duration b. place c. language
Advanced technical training	Head of Soil Conservation, Director of Agriculture, Director of Extension, etc.	Experience sharing Learning new ideas	a. Up to 1 month b. International Research Inst. c. English
Expert workshop	Researcher, teacher or practitioner, well experienced	Detailed exchange of ideas and information. Publication of proceedings	a. 1 or 2 weeks b. Anywhere c. Appropriate language usually English, Spanish, or French
Graduate study for teachers	University teacher, graduate in agricultural sciences or agricultural engineering	Absorb advanced teaching in a subject not previously covered in depth (MSc). Advanced teaching and research (PhD)	a. MSc 1 or 2 years; PhD 3 years b. Out-of country Univ. later in-country c. Language of University
Graduate study for practitioners	Regional agricultural officer. District soil conservationist. District extension officer.	Graduate training in theory and practice soil conservation	a. 9 to 12 months b. Out-of-country univ. later in-country c. Language of University
In-country technical training	Soil Conservation officer. Agric. officer Extension officer	Practical training at design level either by by visiting trainers or local staff	a. Series of 1 month courses b. In-country training center c. National working language
Operate level training	Field assistant Conservation assist. Agric. demonstrator	Practical training at construction level by local staff	a. Series of 1 month courses b. In-country training center c. Local dialect

servation should not be isolated as a separate subject or discipline but should be integrated into land husbandry and soil and water management.

In the author's view, the solution is not to set up a physical center but to create a coordinating agency which could stimulate and encourage research in the different countries, establish standard techniques and equipment, and act as a clearing house for research information. The Benchmark Soils Project might serve as a model. There is no doubt that international support would be readily forthcoming for a cooperative research program because this was discussed and warmly welcomed at a conference at IITA in 1975 (Greenland and Lal, 1977).

TRAINING NEEDS AND CAPABILITY

Relative to training, the author's assessment is that the need for greater activity is more acute than in the case of research. The gap between what is required and what is available is enormous (Table 2).

Let us first define the several different kinds of training and experience which are needed and then consider how the need could be met.

ADVANCED TECHNICAL WORKSHOPS

At the level of senior executives in government service (e.g., Director of Agriculture or Chief Conservation Officer, etc.) the need is not so much teaching or training but to create an awareness of the problem and provide for a sharing of experience and opportunity for the transfer of new ideas and approaches. A good example of filling this need is the Workshop on Soil Conservation and Management in the Humid Tropics which was held at IITA in Ibadan, Nigeria, in June 1975. The proceedings were published as a book (Greenland and Lal, 1977). The participants were all experienced scientists and administrators but not necessarily experts in soil conservation. That one conference alone led to a new surge of international cooperation. There are a number of other examples which could be quoted, but the point is that this type of activity should be increased 10-fold.

EXPERT WORKSHOPS

These provide for detailed discussion and experience-sharing among experts. Examples are the Expert Consultations operated by FAO, for example, that in November 1976, which led to the publication of FAO Soils Bulletin 33, (FAO, 1977a), "Soil Conservation and Management in Developing Countries," and another in January 1977, which led to the publication of Soils Bulletin 34 (FAO, 1977b), "Assessing Soil Degradation." These two meetings led to a great community of interest and the published proceedings are available, but the number of participants has to be small for the meeting to be effective as a consultation among experts. Again, there could be a great deal more of this kind of activity.

GRADUATE STUDY FOR TEACHERS

The men and women who are going to be university teachers need advanced specialist training at the graduate level. On the whole, this group is catered for. Many universities throughout the world offer higher degrees with some level of specialization in soil conservation. Whether this is the best form of training for these men is uncertain but this depends on how much practical experience is expected from university teachers in addition to theoretical knowledge. Most graduate courses are very deficient in practical training. It is appropriate to refer to the excellent example of the University of Wageningen in the Netherlands which operates several out-stations where graduate students spend up to 6 months on a project in the real situation.

The need for graduate courses is adequately met so far as numbers go; but there is some room for improvement by adding practical experience.

Given adequate funding, it would be possible to structure a field training program which, through careful planning and operation, could provide a wide range of practical training experience in a short space of time. For example, a 12-month training program for 15 to 20 people might include six different field situations for 2 months each, where in each situation they would do a detailed study of the local problems, working directly with experienced people on the spot.

GRADUATE STUDY FOR PRACTITIONERS

A more practical, less academic graduate training is needed for the man who is the regional agricultural officer with special responsibility for soil conservation or the area soil conservation officer or perhaps the district extension officer. Until suitable courses can be mounted in-country, this need can be met by graduate training outside the tropics. An example of this is the graduate diploma in Soil Conservation engineering which we have operated by the National College of Agricultural Engineering for the last 10 years, taking an average of 20 students a year. The majority have come from developing countries and have been chosen for this advanced training by their own government and return there on completion of the course. There are other examples of this type of course, usually covering a syllabus much wider than soil conservation; e.g., ITC in the Netherlands (ITC, 1979).

The disadvantage of this out-of-country training is that, like higher degree courses, it is difficult to include sufficient real-situation practical work. Laboratory studies can use artificially generated tropical rainfall; and design exercises can be based on real situations using maps, models, and stereo interpretation of aerial photographs. However, it is not possible to give practical on-site training in things like the laying-out and construction of graded channel terraces nor is it possible to demonstrate different kinds of erosion and practical conservation practices in the field. For this we must turn to in-country training programs.

IN-COUNTRY TECHNICAL TRAINING

No one with experience of developing countries can fail to appreciate the desperate shortage of trained men working in the field, the graduate who designs conservation schemes, and the diplomate who sets out the works. At the moment, there are two types of training programs catering for this need. First, there are the limited training centers. Perhaps the best able to operate their own internal training centers. Perhaps the best example of this is the Central Soil and Water Conservation Research and Training Institute at Dehra Dun in India which has for many years carried out training for field officers of the Soil Conservation Service.

The other type of training at this level is that which is offered by bilateral or international technical cooperation programs. These tend to cover a wider syllabus than just soil conservation. Examples are:

a) The Interamerican Center for Soil and Water Management Studies (CIDIAT) at Merida in Venezuela.
b) A training course recently mounted by the Australian Government through the University of Melbourne for Government personnel in Java.
c) A training course given by the National College of Agricultural Engineering recently for officials of the Department of Agriculture in Sri Lanka.

It is highly probable that there are many other examples which the survey has not encountered. However, even if there are many more than the few mentioned, the overall assessment must still be:

a) at this level there is the greatest and most urgent need for training; and
b) it is at this level that the gap between the requirement and the availability is the greatest.

Training programs for the practical worker in the field must be site-specific and taught on-site in the local country. In some cases, it will be appropriate for the training to take place in a western language; for example, English, French, or Spanish in countries which have a colonial tradition. But in other cases, the training at this level must be done in the local language.

OPERATOR LEVEL TRAINING

The last level to consider is the field assistant, the man who will supervise the unskilled and partially skilled laborers doing the construction. He will probably have education up to secondary school level. Again there is a very serious deficiency in the training facilities available for this type of person; but at this level, the training must be carried out in the local situation, in the local language, and by local people. All too often the physical facilities are available and the reason why there is not a bigger program of training is that there are not enough instructors. It is the common situation that one has first to train the trainers in order to obtain the required multiplication effect.

MEETING THE NEED

Only a handful of developing tropical countries have adequate advisory services operating in the field. Most services are totally inadequate. The need is for trained people, not in ones and twos in each country, but by the hundred. As in the case of research, there is an awareness of the problem and goodwill and financial support which can be brought to bear on the problem. It is a question of how to make things happen. All the points made about research apply equally to training. A coordinating agency is needed which could stimulate and encourage training programs by bringing together the countries or departments which need training, the universities and institutions which have training abilities, and the assistance programs which are able and willing to fund training projects.

Since this coordinating function is required for both research and training, it would seem logical to combine them to form a single unit. One possibility would be to locate it at an institution which already has a strong program of soil conservation research and training, such as the National College of Agricultural Engineering in England. The central coordinating unit could then work through regional centers, for example IITA for Africa, ICRISAT for Asia, and CIAT or CIDIAT for Central and South America.

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