RESEARCH STRATEGY FOR THE IMPROVEMENT OF LAND AND WATER RESOURCES OF THE SEMI-ARID TROPICS OF NORTH-EAST BRAZIL*

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1. INTRODUCTION:

The semi-arid tropics (SAT) of the world are fragile ecosystems which are being substantially modified by the activities of mankind. Increasing human populations have resulted in greater demand on semi-arid regions for providing human substance and the possibility that this may enhance desertification is a grave concern (Hall et al, 1979). These zones are harsh habitats for humans. Water is the single most important natural constraint to agricultural production and human welfare in these regions. However, human tragedy of the drought in North-East Brazil is due as much to the social and economic organization of the region as to climatic vicissitudes (Hall, 1978). When feasible, irrigation by imported water could be used to increase and stablize agricultural production of these regions. However, because of very limited availability of the surface and ground water resources,

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majority of the areas in the semi-arid tropics will continue to depend on direct rainfall for agriculture and livestock, for example, in the North-East Brazil, except for São Francisco and the Parnaiba river basins, opportunities for irrigated agriculture are limited in extent. In addition, traditional irrigation, so far has not been able to make any dent in solving the problem for a vast majority of populance due to a variety of socio-economic and political reasons (Hall, 1978).

The climate of semi-arid tropics (SAT) is characterized by limited, erratic and undependable distribution of rainfall. In North-East Brazil, sometimes a whole year may pass without rain in certain locations. When the rains do occur, the whole year's precipitation may fall in 4 to 5 days. Although the rainy season in normally during the high sun period, any month may have downpours or be completely dry. Variations within a given month of from 0.00 to as much as 1335 mm have been recorded (Hargreaves, 1974). The situation is further exaggerated by poor soil resources and their poor distribuition in this regions.

Bowden (1974) claims that the original vegetation has been perhaps clearad several times in the last 400 years in North-East Brazil, often by 'slash and burn' techniques, which has reduced humus levels and left the soil more infertile. This has also resulted in accelerated erosion leaving soils with cropped rocks and gulley formations in the upper reaches of watersheds. This can be confirmed by visiting already cleared lands. Thus better management of water and soil resources is of paramount importance to the North-East region of Brazil. This region has wide variations in its climate, soils and socio-economic status of its population hence any technology that is to be developed or recommended should suit its variable needs. In the following sections a brief descripition of climate, soils and socio-economic conditions of the North-East region is included. Based on this, priorities for research in the area of land and water management and supplemental irrigation are developed.

2. CLIMATE:

A detailed analysis of the climate of North-East Brazil have been reported by Hargreaves (1973). He has delineated the North-East Brazil into various zones as very arid, arid, semi-arid and wet-dry (Fig. 1) based on moisture availability indices* (MAI) as following (Hargreaves, 1974):

CRITERIA	CLIMATIC CLASSIFICATION	REMARKS
All months with MAI in the range of 0.00 to 0.33	Very arid	Very low rainfall zones
One or two months with MAI of 0.34 or above	Arid	Low rainfall zones
There or four consecutive months with MAI of 0.34 or above	Semi-Arid	Medium rainfall zones
Five or more consecutive months with MAI of 0.34 or above	Wet-dry	High rainfall zones

The Wet-Dry areas are out of the scope of this report. The very arid zones are areas of very low rainfall and in general not suited for rainfed agriculture but water can be harvested for livestock use/or very limited agriculture. The arid zones, are areas receiving 500 to 750 mm rainfall and

*Moisture Availability index defined as ratio of amount of monthly rainfall at 75% probability level (PD) with the amount of monthly potential evapotranspiration (PET).

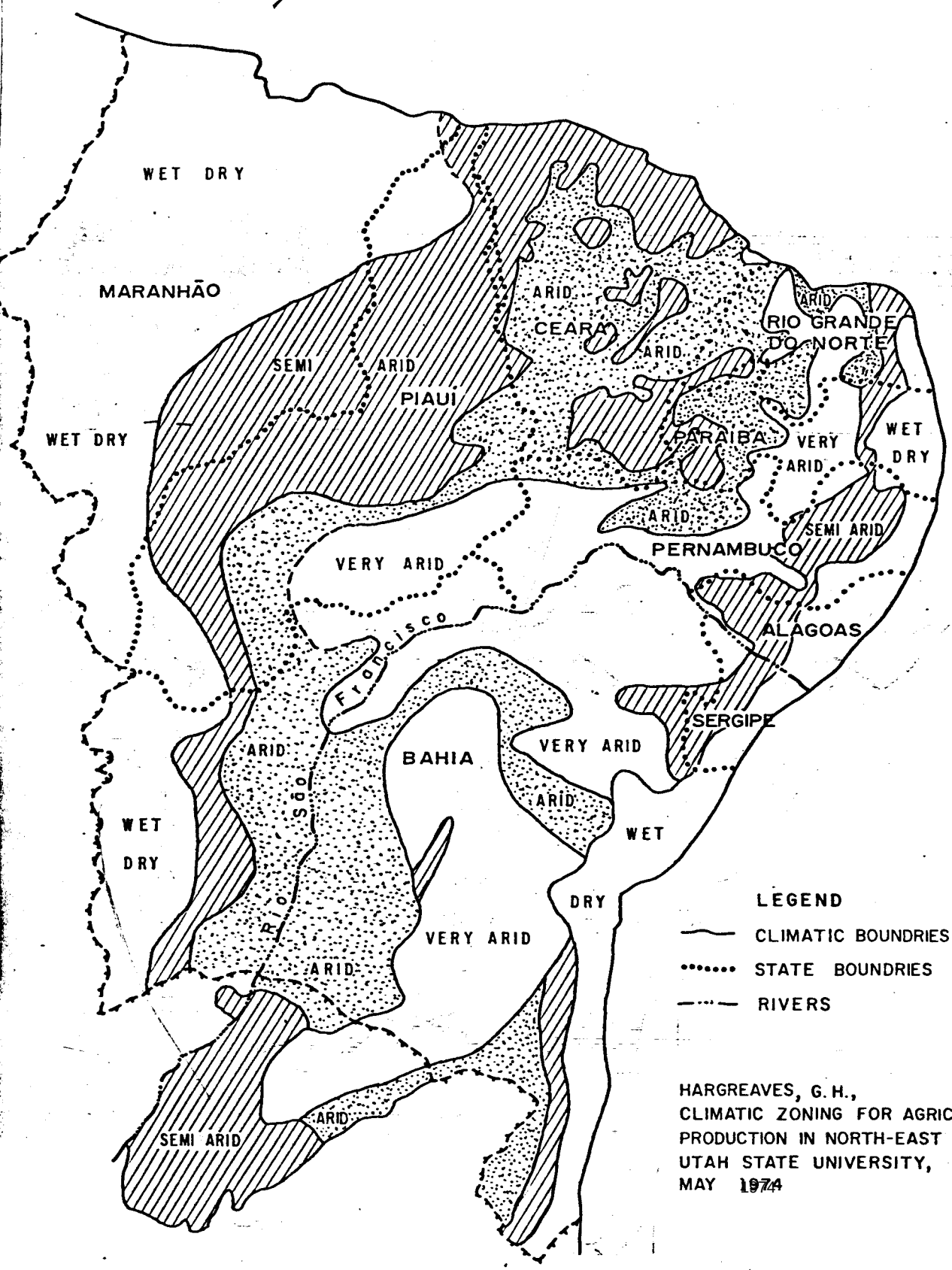

FIGURE. 1 CLIMATIC CLASSIFICATION FOR NORTH-EAST BRAZIL.

have limited suitablity for rainfed agriculture. It is this author's belief that a successful rainfed crop can be grown in many years with appropriate in-situ conservation of soil and water and by backing up the agriculture with supplemental irrigation from harvested water.

In the semi-arid areas as classified above, more rainfall with better distribution is expected and appropriately chosen short duration crops can be grown without additional water. However, proper management and conservation of water and soil along with water harvesting for supplemental irrigation can be easily utilized to boost the agricultural production. In addition, a second short duration crop may be grown on part of the area with the help of collected runoff. Thus, it can be concluded that suitable soil and water management measures which conserve and utilize the limited rainfall better, can provide better environment;

(I) for livestock and fodder production and some very limited agriculture in very arid zones

(II) for stablizing and increasing the production of one short duration crop in arid zones, and

(III) for stablizing and increasing production of one short duration crop with possibilities of producing another short duration crop in part of the area of a catchment in semi-arid zones.

In general descripitions, all these zones classified as very arid, arid and semi-arid are referred to as semi-arid tropics due to similarity in erratic and unreliable distribution of rainfall. But as the climatic classification clearly demonstrates, the capability of each zone varies. Hence these zones should be treated separately for the purpose of developing techniques for managing their soil and water resources.

3. SOILS:

The important soils of North-East Brazil (in SAT region) consist of Planosols solodized, Non Calcic Brown Soils, Solonetz, Vertisols, Latosols and some Regosols (Dematte, 1981). The Planosols Solidized, Solonets Solidized, Vertisols and Non Calcic Brown soils are poor in drainage due to higher clay contents and presence of higher quantities of exchangable sodium (except in Vertisols & Non Calcic Brown Soils). Latosols & Regosols are relatively sandy and do not pose any drainage problems. Thus it can be inferred that problems of management of soil and water for better utilization, are of different nature on different type of soils. However, it can be anticipated that a technology (for soil & Water management), developed for a given soil type with in a given climatic classification can be approximately duplicated on areas of similar soils within same climatic zones (Hargreaves, 1974).

4. SOCIO-ECONOMIC CONDITIONS

Hall (1978) has successfully argued and demonstrated that the 'drought problem' in North-East Brazil is not only a climatic problem. The human tragedy of the drought is a direct result of the way in which the rural structure of the Sertão places thousands of peasants at the economic margin, vulnerable to even the slightest climatic vicissitude. The majority of population directly effected by the climatic vicissitudes are the sharecroppers (parceiros), small holders (minifundistas), tenant farmers (arrendatários) squatters (ocupantes) and wagelabourers (assalariados or diaristas). At best, majority of these people are primarily subsistance farmers in the sense that most of their produce is consumed by the farmer and his family rather than entering the market. In table 1, which is based on the Brazilian Census division (IBGE) study, 1970, breakdown of rural properties into size

Table 1: Distribution of landholdings, sertão, 1970.

States	Size of landholdings (ha)										Total	
	0-1.9		2-9.9		10-99.9		100-999.9		1,000+			
	N	A	N	A	N	A	N	A	N	A	N	A
Pernambuco	15.91	0.50	41.89	5.46	34.98	31.03	6.91	46.03	0.31	16.98	100	100
Paraíba	9.90	0.30	42.62	5.46	40.32	31.16	6.70	29.91	0.46	33.17	100	100
R.G. do Norte	16.39	0.26	34.06	3.03	39.50	21.24	9.24	43.43	0.27	32.04	100	100
Ceará	9.24	0.19	36.71	3.41	40.78	27.16	9.62	44.23	3.65	25.01	100	100
Piauí	44.25	0.98	25.69	2.41	21.91	18.18	7.08	43.20	1.07	34.16	100	100
Bahia	22.00	0.95	42.79	7.98	30.79	36.13	4.22	40.29	0.20	14.65	100	100
Sergipe	19.43	0.38	26.24	2.78	45.57	31.84	8.38	42.96	0.38	22.04	100	100
Alagoas	39.24	2.14	34.89	9.30	22.78	36.70	2.91	38.97	0.18	12.89	100	100
TOTAL SERTÃO	22.24	0.54	35.88	4.07	32.28	26.33	7.27	43.56	1.33	25.50	100	100

Source: IBGE, Agricultural Census, 1970 (Quoted from Hall, 1978).

Notes: N = % of rural establishments

A = % of area covered

categories for the "Sertão" as for 1970, is given. It shows that 58% of holdings are under 10 hectares and occupy less then 5% of the total area. At the other end of the scale, properties of over 100 hectares account for only 8% of the total number but cover 69% of area. (These figures have later been further confirmed by independent studies of selected areas). The 1970 study also suggests that the real income of properties below 25 hectares suffered most during the drought. Holdings of between 25 and 1000 hectares, on the other hand, seemed to be least affected. Thus the land ownership in the interior is very heavily skewed and smaller a farmer more his vulnerability. The vulnerability of particular groups to the drought is a direct product of the landownership structure in the Sertão and the system of tenancy relationships which has grown up around it. The commercializable rural surplus (cattle, cotton and some staple foods) is extracted by a relatively small minority of large and medium-size landowners as well as a variety of merchants or middlemen, while a large part of the poorer population remain dependent on a precarious, largely subsistence agriculture susceptible to minor reductions in rainfall (Hall, 1978).

One of the major conclusion that can be drawn from the thesis of Hall (1978) is that a better redistribution of rural property in the "Sertão" of North-East Brazil will bring a stablizing effect for the majority of the population. For similar reasons many developing countries are infact already taking up redistribution programs. But since redistribution is a socio-political issue it is being presumed for the purpose of this paper that existing land ownership structure will continue for a long time. However, in the present context, if any resource development is to bring any visible effect on solving the problems of the majority of rural populations, it should expressly be directed towards small farmers holding less then 25 hectares of land. Since resource development work is done on natural catchment units, from here it follows that a mini-catchment should be taken as a unit of development.

5. THE APROACH TO DEVELOPING A TECHNOLOGY FOR MANAGMENT OF WATER & SOIL RESOURCES IN NORTH-EAST BRAZIL:

The goal of any proposed technology for managment of soil, water and crop system is to achieve a highest possible water utilization efficiency (WUE) by conserving and utilizing the water and soil resources for highest beneficial use. This aim is to be achieved in collaboration with nature rather than by disturbingor destroying the natural ecosystem. The movement of water follows soil topography in a watershed (Or catchment). The socio-economic conditions of the North-East dictate that the small farmer should be the target of development. Thus, a small watershed or a mini-catchment becomes the natural unit for developing the soil and water resources. This concept has been amply demonstrated at ICRISAT where the first author alongwith Drs. Krantz and Kampen has the credit of developing a small watershed based technology for managing soil and water resources of Vertisols (Sharma and Kampen, 1975, Sharma and Kampen, 1976, Sharma and Kampen, 1977, and Krantz and Kampen, 1978). The recent work of the author on optimization of small reservoir irrigation System for Semi-Arid Tropics (Sharma, 1981), also very clearly demonstrates that a small watershed should be chosen as unit of development of soil and water resources, if optimum benefits of the system are to be achieved. The recent work carried out at CPATSA (Silva and Porto, 1982) in last 3 years has generated some lead data base for such an approach and shall prove useful in generating an integrated technology for soil and water management and supplemental irrigation systems in North-East Brazil.

CPATSA is located in a very arid zone (Petrolina) according to Hargreave's (1974) classification. Thus it becomes responsible for developing a range of technologies to serve very arid, arid as well as semi-arid zones in North-East Brazil. It should be pointed out here that technologies developed for a particular zone (and a particular soil type) can not be transferred in total

to other zones. Similarly efforts at transferring technologies for management of soil and water from other countries with disregard to the conditions of N-E Brazil will prove futile. The approach should be to adapt and modify the available technologies to suit the needs of North-East Brazil without compromising on the principles and concepts.

It is concluded from the above discussion that approach to generating an integrated technology for soil and water management and supplemental irrigation should be:

(1) A small watershed is to be taken as a unit of planning and development of soil and water resources.

(2) The research on development of a technology for soil and water management & utilization should be conducted at atleast 3 locations, namely:

(a) in very arid zones

(b) in arid zones, and

(c) in semi-arid zones

This is to be done in the most predominent soil type of a zone in collaboration with the State agencies and other local agencies.

(3) The development of a technology should be in an integrated manner rather than in components. This should result in development of appropriate models of the proposed systems to facilitate fast transfer of the technology.

(4) After the technology has been developed at research stage; it should be tested at a pilot project stage at operational scale at a number of locations among small farmers before it can be recomended for use, and before heavy investments are made in transfering and executing the technology at farmers level.

Keeping the above discussion in mind, a summary of recent research and

findings for management of land and water resources under semi-arid environments is presented first and then some specific research priorites in the area of supplemental irrigation and soil and water resource development, are presented.

6. A BRIEF REVIEW OF RECENT RESEARCH:

CPATSA is located in a very arid area receiving only about 400 mm rainfall. Based on one of the crop water simulation models (Porto et al, 1982), which quantifies the risk involved in rainfed agriculture, it is estimated that the chances of growing a successful crop at Petrolina (PE) are only 10%. Even at a place like Jaicos (PI) which receives an average of 700 mm rainfall, the chances of growing a successfull crop do not exceed 60%. The viability of life saving or supplemental irrigation is by now well estabilished in many semi-arid regions to reduce the risk involved in rainfed agriculture. At CPATSA recent experiences also show how excess runoff can be used to raise crops in limited area even in very arid conditions like that at Petrolina. (Silva et al, 1981). The major questions still to be resolved are related to optimization of small reservoir systems which is also a topic of another paper (Sharma and Helweg, 1982) in this symposium and has been earlier reported by Sharma (1981).

Some of the recent lead work on resource development under semi-arid conditions have been carried out at ICRISAT (India). ICRISAT has tried a system of broad bed and furrows along with drainage ways and graded terraces for soil conservation and better rainfall utilization. However while this system performed very well on medium and deep Vertisols, it was not effective on Alfisols. Also its viability under very arid conditions has never been confirmed. This demonstrates that the techniques of managing soil ans Water resources may be different under different soil and climatic conditions.

The following section deals with the priorites in research which should be soon carried out for North-East Brazil in order to make a strong foundation for future supplemental irrigation and land and water resource development projects.

projects.

The first proposal is on optimization of small reservoir irrigation system and the second proposal is on development of an appropriate technology for management of soil and water resources in various zones in N-E Brazil. The third research proposal is for defining appropriate water production functions for important dry land crops under high uncertainity. The fourth and final project proposal deals with the rainfall-runoff relationships for small watersheds. The last two projects (third and fourth) are basic in nature. This basic information is needed for planning and designing any land and water resources development works.

5.1. RESEARCH PROPOSAL I:

TITLE: OPTIMIZATION OF SMALL RESERVOIR SUPPLEMENTAL IRRIGATION SYSTEM FOR THE NORTH-EAST BRAZILIAN REGION:

OBJECTIVE:

To develop methods for making better use of the existing system of small reservoirs and to develop a model for optimization of small reservoir supplemental irrigation system for stabilizing and increasing the agricultural production of the North-East Brazilian Region.

SPECIFIC OBJECTIVES:

1. Improvement of existing system of small reservoirs:

(a) To study the hydrologic water balance of a few representative existing small reservoirs in three distinctly different agroclimatic zones of semi-arid tropics of North-East Brazil. The three distinct areas should be in the very arid, arid and semi-arid zones of the North-East Brazil.

(b) To adopt, modify and to develop methods for improving the water utilization efficacy for agricultural production and/Or livestock of the existing small reservoirs in various zones of the Semi-Arid Brazil.

(c) To test and demonstrate the developed methods under on-farm conditions at a few representative locations in North-East Brazil and develop detailed guidelines for use of the execution agencies for modification of the existing small reservoirs such that these reservoirs can be converted into productive agricultual systems.

2. Development of an optimization model for small reservoir systems on small watershed basis:

(a) To adapt and/or develop a generalized mathematical model for optimization of storage capacity, location and design of small reservoir (also called farm ponds or tanks) systems for supplemental irrigation by maximizing net benefits and water use efficiency, and by minimizing investment, associated seepage and evaporation losses, and land occupied by the reservoir. This model should become a tool to provide general guidelines for planning of small reservoir water resources systems in the North-East region of Brazil.

(b) To search, gather and develop the input data needs of the proposed model for a no. of representative locations in N-E Brazil which will be required by the model to be useful as a guiding technique in aiding water resources planning of the proposed region for rainfed agriculture.

The important data needs are rainfall-runoff relations for various zones in North-East Brazil, water production function of various crops grown in the region, cost of excavation as related to lift and lead (cost functions), agroclimatic data e.g. evaporation & seepage rates of various zones in the region, watershed contour maps, information on agricultural input & operations cost for crop production, and knowledge of market conditions of the region.

(c) To test and search locally available cheap seepage and evaporation control materials and methods for controlling seepage and evaporation losses in small reservoirs which in turn will increase the water use efficiency of the small reservoir irrigation systems.

(d) To test the model results under research station & later under on-farm conditions to establish the viability of the model and develop generalized guidelines for the development of small reservoir systems in North-East Brazil.

5.2. RESEARCH PROPOSAL II

TITLE: DEVELOPMENT OF SUITABLE LAND & WATER MANAGEMENT TECHNOLOGY FOR VARIOUS ZONES IN THE SEMI ARID TROPICS OF NORTH-EAST BRAZIL.

OBJECTIVE: Adaptation and Development of suitable technologies for better management and utilization of the water & soil resources in the semi-arid tropics (SAT) in N-E Brazil for stabilizing and increasing the agricultural production of the region on small watershed basis.

SPECIFIC OBJECTIVES:

1. FOR VERY ARID ZONES

(a) To establish a technology for soil conservation in already cleared areas.

(b) To evaluate & develop runoff inducement systems for increasing the available runoff yield from a catchment for water harvesting.

(c) To select and establish appropriate technology for conservation of soil & water and for facilitating supplemental irrigation on the down stream areas of small reservoirs to stablize & increase agricultural production (and/or livestock).

2. FOR ARID ZONES:

To adopt and develop technology for conservation of soil & water on a watershed to stablize and increase agricultural production. The approach here will differ from the approach in (1). Here the major emphasis will be on in-situ conservation of water and soil and suitable arrangement for supplemental irrigation.

3. FOR SEMI-ARID ZONES:

To develop a land & water management technology for soil & water conservation and appropriate surface drainage to create an optimum environment for plant growth for increasing and stablizing the agricultural production of these zones. Here the emphasis will be on in-situ moisture and soil conservation, appropriate surface drainage & supplemental irrigation.

5.3. RESEARCH PROPOSAL III

TITLE: WATER PRODUCTION FUNCTIONS OF IMPORTANT DRYLAND CROPS FOR NORTH-EAST BRAZIL.

OBJECTIVE:

To develop water production function which relate yield, quantity of water and growth stages of important dry land crops of North-East Brazil under high uncertainty.

SPECIFIC OBJECTIVES:

(1) To develop generalized water production functions relating yield and quantity of water use (evapotranspiration) for important dry land crops of North-East Brazil.

(2) To establish the relative yield deficits as effected by relative evapotranspiration deficits at different important crop growth stages for important dry land crops of North-East Brazil.

(3) To establish a criterion for timing and quantity for supplemental irrigation as well as full irrigation projects in North-East Brazil.

(4) To develop a model for minimizing the inherent uncertainities in water production function.

5.4. RESEARCH PROPOSAL IV

TITLE: HYDROLOGY OF SMALL WATERSHEDS

OBJECTIVE: To develop suitable models for predicting runoff under alternate management practices for small watersheds.

SPECIFIC OBJECTIVES:

1. To develop rainfall-runoff relationship under native cattinga conditions for important soil types.
2. To develop rainfall-runoff relationship for cleared lands for important soil types.
3. To develop rainfall-runoff relationship for cleared lands with alternate soil and water conservation practices on important soil types.

6. CONCLUSIONS:

1. The soil and water are national resources. Appropriate development and optimum utilization of these resources will result in the welfare of small farmers in general. These are the farmers which are badly hit by the vagaries of rain. The small wateshed based approach suits the small farmer's requirements.

2. The information which will be generated by research proposals developed here is essential for the development of soil and water resources. Hence these projects should be carried out by CPATSA (EMBRAPA) as a priority.

3. An integrated approach to the solution of the problems of water & soil management can bring visible benefits to the small farmers by increasing and stablizing their agricultural (including livestock) production.

4. To develop technology for management of soil and water resources in N-E Brazil, the technology development research should be carried out in most representative soils of at least the three suggested (very arid, arid & semi-arid) zones in collaboration with state agencies. This will ensure appropriate technology for the whole of North-East Brazil.

5. After a technology has been developed it should be tested at Pilot project scale where selected farmers participate in the adaptation of the developed technology. Only after successful pilot project level testing, it should be recommended for general use.

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