MICROCLIMATE MANAGEMENT AND MANIPULATION

IN TRADITIONAL FARMING

(Report of the Working Group on Microclimate Management and Manipulation in Traditional Farming)

by

C.J. STIGTER, Chairman

WMO/TD-No. 228

Geneva, 1988
WORLD METEOROLOGICAL ORGANIZATION

CAGM Report No. 25

MICROCLIMATE MANAGEMENT AND MANIPULATION

IN TRADITIONAL FARMING

(Report of the Working Group on Microclimate Management and Manipulation in Traditional Farming)

by

C.J. STIGTER, Chairman

1988
COMMISSION FOR AGRICULTURAL METEOROLOGY

Distribution
(i) Members of CAgM
(ii) Members of Working Groups and Rapporteurs
who are not members of CAgM

Subject: MICROCLIMATE MANAGEMENT AND MANIPULATION IN TRADITIONAL FARMING

This report, prepared by the chairman of the Working Group on Microclimate Management and Manipulation in Traditional Farming, was approved by the president of CAgM for publication as a CAgM Report for distribution to its members. This report is printed as submitted, without editing by the Secretariat of the Organization.
CONTENTS

1. INTRODUCTION 1
   1.1 General remarks 1
   1.2 Microclimate management and manipulation 3
   1.3 Working Group activities and future 5

2. SOURCES AND RESOURCE PERSONS 6
   2.1 Sources 6
   2.2 Resource persons 9

3. INFORMATION OBTAINED 9
   3.1 Questionnaire results 9
   3.2 Other information obtained 12

4. STATE OF THE ART REVIEW 14
   4.1 Introduction 14
   4.2 Shading 15
   4.3 Mulching 16
   4.4 Wind protection 16
   4.5 Surface modification 17
   4.6 Drying 17
   4.7 Impact of rain and hail 18
   4.8 Final remarks 18

5. RECOMMENDATIONS ADOPTED BY THE GROUP 19

APPENDICES

I Original text CAgM VIII - Document, pp. 3-4 + Appendix A

II Res. 14 (CAgM-VIII) - Working Group on Microclimate Management and Manipulation in Traditional Farming

III Rec. 3 (CAgM-VIII) - Microclimate Management and Manipulation in Traditional Farming

IV a List of members of the Working Group
   IV b Other collaborators

V a Copy of the questionnaire
   V b Extracts from the 2nd annual progress report submitted to the president of CAgM

VI Case studies and references
   a) Case studies - published
   b) Case studies - planned and ongoing projects
   c) References for a selectively annotated bibliography
   d) References to the main text of the report and to the case studies (see (a) and (b)) not included under (c)

------------------
1. INTRODUCTION

1.1 General remarks

This final report of the CAgM Working Group on Microclimate Management and Manipulation in Traditional Farming addresses itself to those working in agricultural and agrometeorological practice and science. It deals with conditions of low-input farmers (meaning farmers using low external inputs) in developing countries. The word "tropics" is also used below, in a very wide sense as a synonym for developing countries, implying developing areas outside the actual tropics but with comparable conditions. Another synonym sometimes used is "Third World". The term "traditional farming" is used in the sense of the original discussion in the document submitted to CAgM VIII which also provides the rationale of this study (see Appendix I).

This report includes as traditional techniques any technique of microclimate management and manipulation which is known to have been used somewhere in the course of history by low-input farmers anywhere in the world. This includes the now developed world, where certain traditional techniques were first used. This is one of the reasons that the distinction between presently applied techniques and traditionally applied techniques often becomes blurred, a condition strengthened by the fact that certain traditional techniques locally innovated bear close relationships to "imported" ones. The report assesses only the work that has been brought to the attention of the working group.

The first large-scale scientific attempt to review the importance of the problems caused by climate in tropical agricultural production dates back to not more than 30 years (Lee, 1957)*. It had two major objectives. First, to review the state of the art at that time concerning knowledge on the effects of climate upon tropical development for the four areas of crop production, animal production, human health and efficiency and industry. The second objective was "to indicate what further effort is needed to bring that knowledge to the pitch that sound practical guidance requires".

In his foreword Heman Greenwood, as the initiator of the study and chairman of the study group (from which meetings the study was compiled), stated: "Our subject was a complicated one. Perhaps if we had all realized the complications at the outset, we might not have had the courage to start". Still they succeeded, be it with a limitation to the humid tropics. Although some of the optimism expressed is outdated and the role that breeding research was going to play somewhat under-estimated, in the chapter on crop production there is a lot of information relevant to the field of work covered by the Working Group on Microclimate Management and Manipulation in Traditional Farming.

* References are given in Appendix VI, either in the reference list for a selectively annotated bibliography or in the other references of the report given after the first reference list.
In the section "Required Action", sub-section "Management", the following interesting recommendations are given:

- Retention of tree cover in conjunction with low crops;
- Preservation of low covering plants in commercial forests;
- Avoidance of monocultures unless experience has shown adequate adaptation;
- Conservation of soil by whatever physical methods are applicable to the individual situation;
- Selection of native practices well adapted to physical and cultural conditions;
- Introduction of technological methods to the extent that they are adaptable to physical and cultural conditions;
- Improvement of storage facilities in both capacity and protective efficiency;
- Increase of incentives to the individual agricultural worker;
- Judicious use of fertilizers and weed preventives.

The book also states under the sub-heading "Research" in the same section: "It is fairly evident, moreover, that new facts and new knowledge are more difficult to acquire in the tropics, that tropical research is not only more necessary but also more difficult to organize" (Lee, 1957).

Although it is only a relatively recently acquired insight, one thing that is certainly known now is that these difficulties spring from the necessity of studying and understanding complex farming systems and of circumstances of different farmer target groups, if one wants to obtain research results for tropical agricultural development. As clearly shown, after long experience, for example by CIMMYT research workers, even the poorest farmers - presumably the most tradition bound and usually those with least access to information, inputs and markets - adopt certain technologies (techniques) while rejecting others (Byerlee, Collinson et al., 1980). They concluded with evidence that such farmers do not adopt recommendations because they are not suitable for them (compare also Gladwin, 1980; Röling, 1981; Eddy, 1983).

Such conclusions which are now more generally accepted have serious consequences for approaches in all fields of tropical research, including tropical agricultural meteorology and tropical micrometeorology. Such conclusions have also resulted in a growing conviction among tropical researchers that traditional methods and systems which are still practised should be studied, quantified and so better understood before small farmers are advised to change or abandon those methods and systems (e.g. Greenland, 1975; Wilken, 1975; Gliesman et al., 1981; Harrison, 1982; Altieri, 1983; Compton, 1984). Very good examples can be found in agroforestry (e.g. Combe, 1982) and other intercropping (e.g. Okigbo and Greenland, 1976), pest management (e.g. Matteson et al., 1984) and plant protection (e.g. Thurston and Glass, 1984) and water use management in wet (e.g. Morales, 1984) and dry (e.g. Lawton and Wilke, 1979) conditions.

Comparing the earlier recommendations quoted above from Lee (1957) with those from this more recent literature, there are few essential differences. However, we have finally understood that no good research strategy can be developed, no potentially useful results will be obtained and no validation and absorption of such results can take place in low-input agriculture, without the immediate participation of the farmer community. The farmers should be consulted from the very conception of research projects.
(Stigter, 1985a; 1985b) until after validation of research results, successful or not (Stigter and Weiss, 1986); both research and its validation should take place for the largest part in representative farmers’ fields (e.g. Flinn and Lagemann, 1980; Whyte, 1981).

It has been only recently learned also that recommendations on dissemination potential and adaptability of techniques which have been successful under certain conditions, should be carefully prepared. As recently reviewed, operational techniques for on-farm weather advisories in low-input agriculture, will have to satisfy the following conditions (Stigter, 1986):

(a) Bear a low supplementary risk for users in the existing survival and subsistence strategies (e.g. Dyson-Hudson, 1984; Hawskworth, 1984);

(b) Have a degree of familiarity with the ones the users have derived from experience and understanding in the course of time in local innovation (e.g. Morales, 1984; Golob, 1984; Rhoades, 1984);

(c) Be compatible with empirically demonstrated carrying capacity of the ecosystem with which the user is already familiar (e.g. Eddy, 1983; Denevan et al., 1984);

(d) Be compatible with limits in the availability of labour and/or with flexibility in the local conditions for labour input (employment situation; duration, organisation, distribution of labour etc.) (e.g. Rutherberg, 1976; Harwood, 1979; Richards, 1980; Miller, 1982).

Adaptation or development of operational techniques which satisfy the above conditions, from research and validation in farmers’ fields in low-input agriculture, may provide more opportunities than our colleagues had 30 years ago to realize some of the recommendations.

1.2. Microclimate management and manipulation

Although reviews on modification of microclimate appeared around 25 years ago with regard to the then popular arid zone research (Fournier d’Albe, 1958; Van Wijk and De Wilde, 1962), recommendations were largely on transfer of knowledge and experience to that part of the developing world. That has of course been successful only partially. This is largely due to the fact that in most developing countries hardly any attention has been paid to research in tropical agricultural meteorology (with some aspects of agroclimatology and agrometeorological forecasting as exceptions) and in tropical micrometeorology of crops in particular (Stigter, 1981; Stigter and Weiss, 1986).

If anywhere, it is in the tropics that the definition of agricultural meteorology as “the study of how the atmosphere is affected by the production of food” (Monteith, 1985), is most appropriate. Agricultural production there is largely small scale and makes use of microclimate modification. In fact meteorological information can be used in three ways for agricultural purposes: weather forecasting for agriculture, agrometeorological forecasting (WMO, 1981; and for a somewhat different definition, Frère and Popov, 1979) and weather advisories (Stigter, 1984a). For low-input, agriculture problems of communication and absorption capacity exist in addition to the great
differences that are apparent between tropical weather systems and those systems playing a role in forecasting outside the tropics. This makes near real-time weather forecasting for agriculture, other than disaster warnings, less important in large parts of the developing world in comparison with developed countries. In Africa, the most interesting results obtained hitherto with forecasting elements, through the agricultural extension services, were based on evaporation values, crop water use and early identification of seasonal rainfall patterns (Stewart and Hash, 1982). The latter procedure involves elements of non-synoptical long-term weather forecasting and provides recommendations on final planting density and fertilizer use. In Asia, attention has been paid (and collaboration requested for validation of such an approach) for a short-term weather forecasting for rice farmers in the form of simple ranges, following a rather wide but operational division, of selected weather parameters which influence rice growth (Lomototo and Baradas, 1983). Validation reports have not yet appeared.

Agroclimatological data form a basis for land-use planning (ecological zoning) and planning of crop production (e.g. Yao, 1981; Oldeman, 1982; McFarland, 1983; Yoshino, 1984). If made locally operational by national services or international projects, this will have a strong potential for planning purposes in agricultural production. Extension services or other intermediates are needed to get any operational results, which are still rather meagre, to the farmers (Hall, 1983; WMO, 1984). Methodology and time scale for agrometeorological forecasting of crop development, crop disease development and yield are also very suitable for providing planning advice to Government ministries or other planning units and to large agricultural projects (e.g. Frère and Popov, 1979). But small low-input farmers can hardly make use of such near real-time information in their crop management decisions.

However, such farmers do manage and manipulate the physical environment of crops and yields. Quantitative long-term on-farm advice on such management and manipulation practices are termed weather advisories (Stigter, 1984a). Management should be seen here as inadvertent as well as deliberate preservation of desirable characteristics in the environment used for agricultural production, and manipulation as a deliberate generation of such characteristics. Both include modification with respect to natural conditions (e.g. Stoutjesdijk, 1977; 1980). Such an approach with on-farm weather advisories means by definition that we give production advisories regarding use or active modification of meteorological conditions, in or close to the space occupied by crops and animals or their products, to increase quantity, quality and protection of crops, animals and yields (Stigter and Weiss, 1986). If this approach could be made operational it would be the most powerful tool in agricultural meteorology to meet the needs of low-input agriculture in the developing world. Such operational weather advisories to small farmers in the tropics require that recommendations be carefully adapted to both their physical and social environments. Quantitative advisories demand scientific understanding of the existing, often still very traditional systems of the farming communities that have survived for generations in a specific environment (see Appendix I, the discussion in the original document).

One may call this an ethnoscienctific approach (Brokensha et al., 1980), in which first of all knowledge on traditional practices is collected and then such practices are more intensely studied quantitatively. This approach is recommended in agricultural meteorology as well (Wilken, 1972) and case studies on the catalogued examples (Appendix I) are available (Stigter, 1985a). From such studies weather advisories should be derived and validated in farmers' fields, working together with the farmers. This approach
requires collection of existing examples of studies of traditional agricultural methods and practices still in use with components of microclimate management and manipulation. This was obviously the first main task set before the Working Group on Microclimate Management and Manipulation in Traditional Farming.

1.3. Working group activities and future

The terms of reference of the working group are reproduced in Appendix II. CAGM VIII also adopted a recommendation on this subject (Appendix III). Names of Members and "co-opted" correspondents are given in Appendices IVa and IVb respectively.

To meet the requirements of the term of reference (a), a questionnaire was sent by WMO (see Appendix Va). An extract from the second annual progress report to the president of CAGM, summarizing conclusions drawn from the replies to the questionnaire, is reproduced in Appendix Vb. Section 3 of this report deals further with details of the questionnaire replies.

In accordance with the term of reference (b), the information solicited and received with the questionnaire from members of the working group, from correspondents and from other resource persons in this field of research, has been summarized in Section 3 of this report. Some case studies and more than 100 references intended for a selectively annotated bibliography are presented in Appendix VI. Such a bibliography should be selectively annotated on aspects of traditional techniques of microclimate management and manipulation and/or on a micrometeorological basis for better understanding such techniques.

To comply with the term of reference (c), the available literature has been summarized in Section 4 to provide a state of the art review. An overall view of the subject has already been given in the introduction.

As regards the term of reference (d), special efforts were made to contact CGIAR and other international agricultural research institutes. This is reflected in the review of and discussion on results and information obtained (Section 3).

With regards to term of reference (e), at the informal meeting of the working group in Geneva, October 1985, a round table was organized on this item. As stated in the report of that meeting (Stigter, 1985h), it was concluded that very little of the collected information could go into CARS-Food at the current stage.

Concerning term of reference (f), two annual progress reports were submitted by the chairman. A draft of the final report was sent in September 1985 to the members of the working group and discussed at the informal meeting in Geneva. The present report incorporates comments, conclusions and recommendations made at that session (Stigter, 1985h).

This report addresses itself not only to those who contributed to its contents but also to new potential contributors, to update this kind of information. To continuously encourage collection and use of such information the working group decided:

(a) to facilitate the sending of new or related information through pre-addressed tear-out sheets which can be easily filled in:
(b) to suggest to WHO to give this report and these sheets a wider dissemination than CAGM members only;

(c) to stress that the work should be seen as an ongoing activity, especially with respect to summarizing new information, the proposed annotated bibliography and the provision of information suitable for CARS collections.

2. SOURCES AND RESOURCE PERSONS

2.1. Sources

Development of suitable and more efficient farming systems in the tropics must be based on gradual improvement in the existing farming systems (e.g. Greenland, 1975; Lal and Cummings, 1979). In the ethnoscientific approach, the actual primary source of knowledge and information on traditional techniques is the community of traditional farmers. The term traditional farmers is used as including cultivators whose knowledge and methods are derived from individual and social experience and who use only locally available energy and materials for environmental management (Wilken, 1972). The word traditional in this sense applies for example to north American agriculture prior to the European settlement, to that immediately after settlement, which was a mixture of indigenous and imported techniques, and to their agriculture of the first quarter of this century (Greenwood, 1980; Loomis, 1984). This immediately shows that change and diversity are as much concepts in and facets of traditional agriculture as those of today. This is not the place for a philosophical treatment of what local knowledge is and what evolution and change of such knowledge means. One can leave this to the sociologist/anthropologist (e.g. Geertz, 1983). But a study of local traditional resource management practices should be one of the corner-stones for any integrated attempt to improve rural living conditions in developing countries. There is a growing awareness of this truth as recent specialized publications show (Brokensha et al., 1980; Klee 1980).

From these publications as main sources the following important conclusions can be drawn:

(a) There is no further need to "prove" the importance of the essentials of traditional knowledge in trying to assist developing countries to find strategies to cope with expectations and realities of improvements in living conditions, with the consequences of population growth and with the prevention and calamities of natural disasters (Hewitt, 1983).

(b) There are large regional differences in what is practised and therefore there is a need for specific studies to be made in the field of work. Traditional systems in Africa should receive most attention, because low-input agricultural development can profit most from building on traditional techniques in that continent. However, microclimate modification is recognized only in very few studies as requiring little capital investment for considerable yield increases in low-input agriculture (Beets, 1978). Moreover the actual African traditional agricultural systems are complex in composition and therefore rather difficult to quantify, especially with the limited resources available. This is one of several reasons that intercropping techniques have been neglected
in the scarce agricultural research in Africa (e.g. Belshaw, 1980; Beets, 1982). In the Middle East (and parts of Africa with comparable dry climates) one can see more than anywhere else the consequences of misuse of modern technology and pressure on scarce resources. Management of water and soil has several aspects with microclimatic components (e.g. water use efficiency in irrigation, erosion prevention in desertification, extensive agro-forestry as for example fuel-wood growing in combination with agricultural crops or animal husbandry). In Asia, microclimate management methods are explicitly listed by Murton (1980) for South-Asia and he states that traditional farmers there have achieved considerable control over individual plant or small plot microclimates, with shade management as the most widespread and with mulching only to a limited extent. In East Asia, it is the very sophisticated peasant gardening ecosystem which supports something of the order of a quarter of the world's population, that employs several microclimate manipulation methods, with nursery bed temperature and water within field embankments mentioned as the most important parameters modified (Witney, 1980). Forms of shifting cultivation with microclimate management components are also still abundantly practised in South and South-East Asia. Other soil and water conservation measures indirectly managing the microclimate are mentioned for the South-Pacific by Klee (in Klee, 1980). Microclimate management and manipulation in Latin American traditional agriculture is listed by Denman (1980) as widespread and as comprising temperature control, dew inducement, shading, wind breaking, reduction of evaporation and transpiration, reduction of rain impact, and infiltration control as well as the major means of water control in irrigation and drainage. His nomenclature is based on Wilken (1972).

(c) Although traditional African agricultural systems have been described, they have been studied the least. Our field is the worst off, the description of microclimate modification being too rare (Allan, 1965; Acland, 1971; Wilken, 1972). Imported methods of microclimate manipulation such as shelterbelts have also been practised for 20 years in Africa but very few (scientific) reports are available on their influence on the environment of the protected areas. This applies even to Nigeria, the African country with most agricultural research (Ujah and Adeoye, 1984). Micrometeorological work in Africa is rare and has been carried out only on cash crops (e.g. Woodhead, 1968, 1969). However, no reference is made in such work to traditional practices. Descriptions of South Asian traditional techniques had to be dug up by Murton (1980) from colonial District Gazettes and books on Indian agriculture from 1893 and 1928. Early measurements of the microclimate of crops in India, in style with the basic research work in Europe at that time, were reviewed by Ramdas (1951). However, it was not possible to trace any reviews of experimental studies or even descriptive reviews on traditional methods of microclimate modification from that or any other part of the Third World after 1972, the year in which Wilken concluded that such studies did not exist. For that reason, a newspaper contest was organized in Tanzania to obtain more information than a simple listing of traditional techniques (Stigter, 1982a, 1985a). Such a questionnaire-type of
approach to obtain a review of local knowledge has much to recommend it, provided it can be reinforced by observation and participation (Richards, 1980), and this is what should be organized in research follow-ups, which are almost completely lacking at the moment.

(d) It was agreed that for Europe, North America, USSR and other countries with largely advanced modes of agricultural production, the terms of reference of the working group should be considered as referring only to institutes, organizations, departments, individuals, dealing specifically with (traditional) tropical or other low-input agriculture. Exceptions could be very specific historical examples on microclimate manipulation and management techniques applied in the past, or examples from still existing pockets of largely traditional agriculture within these countries, or examples of techniques and methods applied nowadays almost the same way as in traditional agriculture. Examples of still existing pockets of largely traditional agriculture in North America, which are ignored by Loomis (1984), are supplied by Greenwood (1980). Microclimate management examples by the Hopi Indians and the Canadian Atlantic subsistence farmers were mentioned explicitly by the latter, but no references were given to further studies of these aspects. However, one of his final remarks cannot be denied: "Indeed the future of food production in North America may well hinge upon our ability to integrate small, labour-intensive, traditional units within the mainstream of commercial agriculture". As long as both this kind of alternative agriculture and the low-input traditional agriculture of the developing world get indeed the same scientific basis (Altieri, 1983), the scientific resources put into and the results yielded from these studies in the developed world may at least become a new source for studying techniques in tropical low-input agriculture. Research in bilateral, international and multilateral development projects has to rely these days almost exclusively on either the little that was done in colonial times on small-scale low-input agriculture or on what has been obtained under non-tropical conditions.

(e) Microclimate research is no exception to the above-mentioned rule, if it is not, as said earlier, the worst off. Indeed traditional microclimate modification practices have only been studied systematically and experimentally in the Western world (Hillel, 1972; Tanner, 1974; Gebber and Hopen, 1974; Gerber et al., 1974; Barfield and Gerber, 1979; Arkin and Taylor, 1981; Hatfield, 1982), in the USSR (e.g. Holzberg, 1961; Voeykov, 1963; Karing, 1971; Shulgin, 1972; Adamenko, 1979) and in Japan (Mihara, 1974), where the history of this work goes back several thousand years.

The above implies that for tropical low-input agriculture only a system of individual case studies, whether published, in progress or planned, would have to be relied upon for the report of our working group. The sources of such case studies could only be uncovered by contacting individuals and from a few relatively high level tropical journals.
2.2. Resource persons

As Wilken was the only resource person originally identified, members of the working group, correspondents to be recruited from CGIAR and other International (Research) Institutes and Organizations in (and on) the tropics, agrometeorologists receiving and returning the WMO questionnaire and individual (research) experts working in the tropics on relevant issues were relied upon to collect the case studies concerned.

For contacting relevant agricultural (research) institutes, organizations and individual experts, addresses given in WMO's Guide to Agricultural Meteorological Practices (1981) and the very useful guide recently issued by Manintveld and Soree (1982) were strongly relied on.

3. INFORMATION OBTAINED

3.1. Questionnaire results

The basic aim of the kind of work in which the working group is involved is to find a micrometeorological basis for the application of traditional agricultural technology (of microclimate management and manipulation) in the management of tropical eco-systems (Comp. Janzen, 1975). This means that a pure listing of examples will only be a starting point to get an impression of the fields most urgently in need of or most fruitfully served with such a micrometeorological basis. The listing abstracted from the questionnaire is given below with an indication as to which of the case studies derived from the questionnaire material can be found in Appendix VI.

Of the 153 Member countries of WMO, 46 replied and some relevant details of these replies have been reproduced in Appendix V. Of these, nine countries only indicated the existence of traditional practices, without further details being available from publications. These practices have been listed below, following the classification of Appendix I.

AFRICA

Guinea (Republic of Guinea)
A2, B2ii, C2, C3, D1, D2, F2, G1, G2, H, I, J1, L1i, L2, M, N, O, P1, P3, Q, R

Kenya
Most abundantly: A1, A2, D, E, F, G, J21, J2ii, L, M, N, O, P1, P3, R
Not practised: A3, B, C3, H, K1

Malawi
J1, I

Sudan
No specification

Zambia
F, O
LATIN AMERICA

Colombia
C3, J1i, L1i, L2i

Panama
A1, C3, D1, E, J1i, J1ii, L2i, L2ii, O, P

MIDDLE EAST

Iraq
C3, F, L2ii

ASIA/PACIFIC

Fiji
A1, D1, L2ii

Two Members, El Salvador and Korea, indicated the existence of plans only. These have been included as case studies of such planned projects in Appendix VI. Nine countries supplied information from published literature, which is summarized below.

AFRICA

Nigeria

Two institutes were indicated as carrying out oil palm research and general agricultural research respectively. From the publication titles on oil palm no involvement with traditional practices in respect to microclimate were apparent. There were also no references to peasant practices in the material received. Published work on shading, wind breaks, mulching and tillage were received, more than from anywhere else in Africa, but yield observations are predominant in the publications. The scarce, little detailed measurements of microclimate modification (except soil temperature) had nothing to do with traditional farming practices; the latter have not been studied for comparison. This is not an exceptional situation. The same applies for example to a scientifically sound book as that of Lal and Greenland (1979) on soil physical conditions and crop production in the tropics.

This most likely confirms what has recently been said on research and agricultural development in Nigeria in general (Anonymus, 1982). The research of its sixteen agricultural research institutes is ineffective due to two main causes: an ineffective communication of new technologies and the issuing of recommendations on technology not appropriate for Nigerian farmers. Both point to not enough attention being paid to traditional farming systems and techniques.
Tanzania

The examples from Tanzania come from the research work of the chairman of the working group (Stigter, 1985a). In a preliminary report on the newspaper contest (Stigter, 1982a) the following techniques were indicated as most abundantly practised in Tanzania:

A1, B2ii, D1i, F1, F2, G2, I, J2ii, L2ii, O, P

No other published or planned micrometeorological or other quantitative research on traditional methods used have been found. Recently published and planned work on the above subjects is taken up as given in the case studies of Appendix VI. In the annotated bibliography, review papers on shading, mulching, wind protection and surface (properties) modification are included as well as a synopsis of the final contest report (Stigter, 1985c). The review papers include examples from the only earlier source on East African microclimate modification examples (Acland, 1971). Published case studies are all on grass mulches.

The ongoing work in Tanzania, as part of a project which also includes recently started research in the Sudan and Kenya, is given in Appendix VI as well.

ASIA/PACIFIC

China

Half of the examples given in this answer are of the C3 type, using transparent plastic. The others are showing G1, L and unspecified research on cold injury in rubber trees.

Indonesia

Areas indicated to be found in Indonesia are:
A1, A2, D1, F1, G1, O2

However, literature received does not show any relationship to methods of traditional microclimate modification.

Japan

The review of examples of mostly older and a few recent research undertakings sent by Japan excellently fits the aims of the working group. The post-war research of the fifties appears very relevant to its work and one can learn much, especially from the results of studies on wind, air and soil particle movement manipulation, soil (ridge, slope) and water (rice field) temperature modification, radiation (loss) protection and mulching. As far back as thirty years ago also some essential results on intercropping were already obtained in Japan (Abe and Takahashi, 1959).

The areas reported on are:
A2, B2, C, E, F1, F2, G1, G2, I, L1, L2, N, O1, O2, P3
Examples which have been included in the case studies are:
cultivation on staircase-like slopes; effects of straw-matting; wind-break influence on water temperatures; straw fences and bamboo-blades as wind breaks; effects of shelter-hedges against typhoons and the control of wind erosion by several surface modifications. Most modern modifications listed were of the C3 type.

Malaysia

Areas reported on are:
A1, A2, D1, F1, G2, I, J2iii, O2, P1, P3, R

Projects are in progress on soil erosion monitoring, simulation and control.

Papua New Guinea

An important publication on traditional soil conservation in Papua New Guinea was received (Wood and Humphreys, 1982) and quoted from abundantly in the second annual progress report. This has been included in the references of the annotated bibliography; a project in progress in the same field was also indicated (see Appendix VI).

EUROPE

From two European countries, France (especially INRA) and the Federal Republic of Germany, information was received on projects which are carried out by (or supervised by) European scientists in or in relation to developing countries. In addition to the details of work in field C3, references and information on G1, L and O1 have been received from France. The results of this work carried out in the seventies in France are now used in an extrapolation to projects in progress in developing countries. No case studies are as yet provided. Some of this work has been taken up in the annotated bibliography and some in the planned and ongoing projects sub-section. Also in the case of Germany, local work has been indicated on G1, I and L2. The latter work has been included in the case studies of Appendix VI.

Putting all the above replies to the questionnaire together, it may be observed that wind protection, when taken to include G1, L(1 + 2, i + ii), O1 and P3, is the most widely found traditional technique of microclimate modification. This is followed at some distance by a large group of other abundantly applied techniques: shading (A), mulching (F), surface modification (E + I), drying (D1 + J(1 + 2, i + ii)) and impact of rain and hail (G2 + P(1 + 2)). This group is the same, with the exception of storage (D2 + G2 + J(1 + 2, iii)), as singled out by Stigter (1985a) from the Tanzanian contest only. The storage item has been mentioned less in the answers to this general questionnaire than in the Tanzanian contest material. But the subjects of drying, storage and impact of rain and hail are most heavily researched and these are again considered in the state of the art review in Section 4.

3.2. Other information obtained

The contribution from the CGIAR-institutes has in fact been disappointing. Much sympathy has been expressed by CIAT and ICRISAT, correspondents were nominated by six other of these institutes, and ideas for
contributions were expressed by IIITA (member of the working group) and IRRI; but only four of these institutes contributed some relevant material: IPC (Peru), ICARDA (Syria), IIITA and ILCA (Ethiopia). This material has been taken up in Appendix VI. IPC recently met the request for a list of practices of microclimate manipulation for which it would be interested in developing (further) research:

A, B, C, D, F, G, I, J, L and R

A list of such practices for (further) research was also received from ICRAF:

A1, E, F1, G1, L and M

The USSR provided a short review of their basic results as follows:

(i) A procedure has been developed for microclimatic observations of agricultural lands and for appropriate summaries.

(ii) The basic characteristics have been shown of microclimatic variability of climate elements in various geographic zones as affected by the inhomogeneity of the underlying surface.

(iii) Regional studies are underway for the improvement of quantitative estimates of microclimatic resources in various physiographic conditions.

(iv) Experimental studies have been made on the effects of microclimate on the productivity of main crops.

(v) Techniques are being developed for the consideration of microclimate resources in growing main crops and yield programming.

English abstracts received from relevant USSR publications will be included in the annotated bibliography.

FAO also provided a series of examples of microclimate management and manipulation. These were in the fields of:

A, D, E, G, L, N, O and P

Some have been included in the Planned and Ongoing Projects Section of Appendix VI.

The Institute of Forestry and Soil Science, Academica Sinica, Shenyang, China sent a book entitled "Farmer shelterbelts", in Chinese. Pictures and equations therein show it to be very relevant to our work. English abstracts and lists of contents of some related papers and journals show that this Institute works on sunlight and wind microclimate and water budgets of forests and shelterbelts. Correspondence with the Institute of Geography, Academica Sinica, revealed that not much research has been done in China on the subject of the working group. Soil and water management are receiving more attention, but agrotopo-climatology and even soil erosion protection need much more attention.
Several individuals and groups interested in the study of tropical agro-ecosystems from the low-input point of view have been contacted. Two of them especially may be sources for other interested research colleagues. The group of Prof. Egger of the Botanical Institute of the University of Heidelberg works together with GTZ, the German Development Cooperation Organization, to study and define "ecofarming" in the Third World (e.g. Egger, 1981; 1983). The socio-ecological study of complex tropical agro-ecosystems (stability, diversity, productivity, nutrition cycles) is an important first step (e.g. Fernandes et al., 1984; Gliessman, 1984; Miguel and Hladik, 1984), on which should follow a quantification of such systems in terms of consequences of (changes of) management practices. In the Netherlands an Information Centre for Low External Input Agriculture was recently established by ETC (Educational Training Consultants). It issues a small English newsletter with articles and relevant literature abstracts (ILEIA, 1984; 1985). Microclimate management should become known among those groups and should benefit from their ecological outlook and small farmer oriented approach.

The above-mentioned are activities in bilateral development aid and a third source of this kind is formed by many more efforts in France. From Dr. Guyot information on ongoing projects was received and a score of addresses to be contacted on projects from Dr. Balidy. Both are employed at the Station de Bioclimatologie, Montfavet. Case studies and Planned and Ongoing Projects from these sources have been included in Appendix VI. Some published work can already be found in the references for an Annotated Bibliography.

Other information received confirms the picture of scarce and diffuse sources of research results in micrometeorology to better understand traditional techniques of microclimate management and manipulation. The approach of Appendix VI was therefore the only strategy left for the purpose of the working group.

4. STATE OF THE ART REVIEW

4.1. Introduction

The original document submitted to CAgM VIII by the United Republic of Tanzania recommended the nomination of a rapporteur. This proposal was upgraded, via the formation of a group of rapporteurs from different regions, to a Working Group on Microclimate Management and Manipulation in Traditional Farming. Although some members of CAgM believed that it was too early for a full working group, the group started with the hope that it would uncover more than one was able to expect on the basis of the Tanzanian experience. This hope has neither been completely met nor has it been completely idle.

The replies to the questionnaire and other information collected have largely confirmed the importance and urgency of earlier selected subjects for (further) research. It has also confirmed the virtual absence of micrometeorological studies of traditional techniques in the developing world, reinstating earlier conclusions (e.g. Robertson, 1980). Case studies were collected mainly from aid programmes in Tanzania and Saudi Arabia. Early Japanese work was extremely relevant and several planned and ongoing projects were collected in which highly useful knowledge and experience obtained in the developed countries is used, extended and multiplied in the conditions of the developing world. The picture of present or planned Chinese work as presented may not be complete.
As follows from the references for the Annotated Bibliography, a
scientific approach and basic knowledge of micrometeorology exist that should
be transferred and applied to meet the challenge of tropical problems
(Comp. Stigter and Weiss, 1986). But operational advice for tropical crop
space management which can be disseminated through extension services is
scarce. Therefore only a short summary of what can be concluded from the
references so far collected for a selectively Annotated Bibliography and from
the Case Studies on the most important fields referred to above is provided in
the following paragraphs.

4.2 Shading

The literature on shading is almost completely on agronomical aspects
and limited largely to cash crops (Stigter, 1984c; 1985a), although
descriptive models of a more physical approach have been outlined (Smith,
1972; Stigter, 1982b). A quantification of traditional shading techniques
from the micro-meteorological point of view will most likely contribute much
to solving remaining and new agronomical controversies and ignorances. This
may be expected to apply to such important questions as re-introduction of
light shade in tea production (Othieno, pers. comm.; Obaga, 1984) and other
shade/economical yield reduction in different patterns of intercropping
(including agroforestry), shade/weed reduction interaction patterns for
different geometrical configurations, the "mulch character" of arrays of
shading objects of different densities, the effectiveness of a diurnal shading
pattern of single or alley trees and high plants, etc.

Fuchs (1972) was among the first to remark that "it seems that
insufficient attention has been devoted to the controlled transformation of
the radiation climate. Manipulation of the foliage cover density which
modifies the radiation absorption has been used for centuries by foresters to
promote forest regrowth and to improve the shape of trees. (...) However, most
of the techniques used to date are based on traditional and empirical
knowledge rather than on physical theory. (...) As a result of the theoretical
and technical shortcomings, the radiation balance control based upon crop
architecture still belongs to the "trial and failure" approach". Although for
simple monocultures conditions have improved over the past decade, the above
remains largely true for unclosed, ageing and geometrically more complex
canopies. Simple but relatively operational approaches such as those proposed
by Fuchs (1972) and Jackson (1983) require (components of) the radiation
balance underneath the canopy to provide a check on these analyses. One of
the few papers mentioning radiation and microclimate in multiple cropping
systems (Allen et al., 1976) states that "understanding crop ecology of
monocultures has not been rapid; understanding the crop ecology of
polycultures has (only) begun ...". It should be mentioned in this respect
that one of the problems arising is the sampling of polyculture systems such as
agroforestry and other forms of intercropping. There are strong
indications that existing solarmeters for integration of canopy transmission
at different levels (e.g. Lang, 1978; Green and Deuchar, 1985) give more
problems in the tropics than elsewhere (Stigter and Kainkwa, unpubl.). Simple
quantification methods for such systems should be tried (e.g. Adams and Arkin,
1977; Stigter et al., 1984a; Stigter and Kainkwa unpubl.). Many traditional
shade manipulation methods are known (e.g. Stigter, 1984c) and references to
deliberate shade modification bear photographic evidence of that (e.g.
Stigter, 1984b; Altiernri and Farrell, 1984; Sharma and Ranganathan, 1985).
Better understanding awaits better quantification adapted to the complexity of
the agro-ecosystems concerned (e.g. Ewel et al., 1982).
4.3. Mulching

Reviews of mulch use by traditional farmers in general and by Tanzanian farmers in particular have been published recently (Stigter, 1984d; 1984e). To an existing operational technique to determine soil thermal homogeneity (e.g. Stigter, 1985d) an operational method to quantify thermal efficiency of mulches has been added (Stigter et al., 1984b, 1984e; Othieno et al., 1985). But it is also essential to understand more quantitatively mechanical soil protection properties of local mulches in the widest concept of the term "mulch", (Stigter, 1984d) with respect to water (rain drop and run off) and wind erosion (e.g. Guyot, 1980; Lyles and Allison, 1981; Unger and McCalla, 1981; Lal, 1984; Gregory, 1984; Lyles, 1985; Meyer and Moldenhauer, 1985), mulch shading properties for weed suppression (Stigter and Weiss, 1986), shading and insulation properties of local mulches for quantification of evaporation suppression and their modifying properties of soil physical conditions in general (Russell, 1973).

In the case of traditional mulch application, the labour factor and the competition for water, nutrients and space of live mulches or artificial mulch material grown for that purpose have to be looked into in the context of farm management strategies (e.g. Akobundu, 1982). Earlier reviews of mulching practices (Davies, 1975a; 1975b) have to be updated in these and the other above-mentioned directions.

4.4. Wind protection

Apart from soil erosion effects already indicated above, wind has a considerable variety of often incompletely understood influences on plants and animals (e.g. Grace, 1977; Grace, 1985). Earlier wind protection literature has been extremely well covered by Guyot (1963) and especially by Van Eimeren et al. (1964) and more recently by Sturrock (1975a; 1975b). Special attention to strip cropping as a form of multiple cropping with wind protection properties was given by Radke and Hågstrom (1976), although any single reference to tropical conditions is lacking. Attention to techniques of traditional wind protection in the tropics is of very recent date only (Stigter, 1985e).

The most important conclusion of the last-mentioned study is that hardly any research results exist on the principles of even the two most common traditional techniques: around the field barriers and wind reduction by scattered objects as single plants and groups of plants, trees, patches of bush etc. A very small amount of information has been reported on the around the field protection (Van Eimeren et al., 1964; Guyot, 1975), although descriptions of its existence in dry regions go back as far as the fifteenth century (Lawton and Wilke, 1979). Research on wind reduction with scattered roughness elements is even less reported (e.g. Hagen and Skidmore, 1974, calling it "an untried way"), with the exception of cases where we can speak of a canopy (e.g. Cionco, 1993).

Although there is no doubt of the importance of wind breaks for improving the water use efficiency of crops under conditions of high sensible heat advection (e.g. Hagen and Skidmore, 1974; Brandner, 1982; McNaughton, 1983) the long-held view that conservation of water is the main benefit of wind shelter (e.g. Van Eimeren et al., 1964; Rosenberg, 1967) is now rejected (Grace, 1977; Sturrock, 1978). This means that in research on traditional microclimate management and manipulation techniques, also morphogenetic responses (Jaffe, 1980), direct mechanical injuries (e.g. Casada
et al., 1980a; Armbrust, 1985) and sandblast damage by soil particles (e.g. Fryrear and Downes, 1975; Armbrust, 1979; 1985) have to be taken into consideration when wind reduction is studied. The protective configurations to be studied, as well as the observations and measurements to be made on water use efficiency effects and the other above-mentioned responses and damages of plants and trees to and by wind, will therefore present two specific problems in the tropics, like in the case of shading: sampling problems and instrumental problems. Again, under tropical conditions of work, with poor infrastructure and low resources, there is an extreme need for developing simplified multi-point equipment (Comp. Neal, 1975; Casada et al., 1980b; Stigter and Uiso, 1981; Stigter et al., 1984c).

4.5. Surface modification

Surface modification can be defined as: decreasing or increasing the exposure of surfaces to the atmosphere or modifying directly their original properties to change the environmental impact on these surfaces. If accepted in this wide sense hardly any other subjects than those already reported may be expected to be mentioned under this item (Stigter, 1985a; 1985f).

Shading, mulching and wind protection mainly change surface exposure without primarily modifying the initial surface properties. But in some cases the (sub-)surface properties themselves are modified to obtain the objective concerned. Tillage as a form of dry mulching is such an example (e.g. Unger and McCalla, 1981). And changing the surface geometry, as in ridging (Stigter, 1985g) or digging pits, among other things creating differences between neighbouring surfaces in impact of radiation and wind, is another example. In both examples a change in thermal and moisture properties of soil near (part of) the surface is involved as well, as in the case of irrigation and drainage, perhaps the most ancient traditional practices of microclimate manipulations. Colouring the surface to influence radiation reflection is again another example of impact changing (Davies, 1975b; Stigter et al., 1984d).

The above techniques are applied on the bare soil surface. As soon as one deals with composite surfaces, like a crop surface or another terrain with vegetation, direct change of original properties of the surface include such practices as pruning, thinning, weeding, clearing and burning (e.g. Savage, 1980). And indeed such practices change environmental impact on these composite surfaces but research literature on traditional practices of heat and moisture flow manipulation hardly exists. A few less widely applied techniques are mentioned by Stigter (1985f).

The above are the four subjects which were singled out by Stigter (1985a) as the ones which most need research on traditional techniques. Work in the remaining two important fields, as assessed from the WMO-questionnaire, is not as such less important or less urgent, but these subjects are better covered in existing literature. To traditional drying this applies only partially as this kind of simple drying in the open has not been researched appropriately.

4.6. Drying

If examples of surface modification in Section 4.5 had not been limited to specific E+I-examples, most traditional techniques of yield (product) drying could fit in there, as they imply modification or selection
of the surface on which the drying takes place or of the surface of the produce to be dried (Stigter, 1985a; 1985f). As mentioned before, research on simple traditional drying in the field of growth or elsewhere before storage is virtually non-existent, although the detailed indigenous empirical knowledge is worth thorough testing and investigation (Stigter, 1985a; 1985f). Drying in connection with traditional storage has been adequately covered by the abundant storage literature quoted by Stigter (1985a). This report will not deal with storage as it was not considered as one of the most important topics on a worldwide scale, although it is definitely extremely important in Africa as a research subject for studying traditional techniques (e.g. Golob, 1984).

4.7 Impact of rain and hail

Also impact of rain and hail belongs to the subjects reasonably covered in the literature, mentioned in the section on mulching. This does not mean that there is a lot of operational knowledge and a score of operational techniques available for the Third World (Wood and Humphreys, 1982; Blaikie, 1985). But it is a problem shared by agriculture outside the tropics and therefore more quantitative research has been done on these impacts, especially on raindrop impact and resulting soil splash (e.g. Jackson, 1977; Lal, 1984). Recent work on hail impact has been reviewed by Miller (1981). Special care by farmers for crops injured by hail damage is mentioned by Uemura et al. (1974).

4.8 Final remarks

Traditional forecasting of the rainy season apart (Jackson, 1982), all relevant groups of traditional techniques which should be researched to generate on-farm weather advisories have been reviewed above. The general recommendations which follow from this work are basically not different from the ones quoted in the introduction from Lea (1957). However, studies of local systems or of the use of traditional local principles to develop and disseminate improved systems (e.g. Waddell, 1983; Gliessman, 1984; Akroyd, 1985) ask for in situ trials. Recommendations based on these trials ask for on-farm validations, which may convince participating farmers and extension workers of the potential for efficiency increase and dissemination of traditional experience. The more quantitative knowledge becomes available and the more cause-and-effect relationships are discovered, the more successful validations and applications of improved techniques of microclimate management and manipulation will become. The Case Studies in Appendix VI are the first steps on this road, whether finalized, ongoing or planned. The material proposed in the Annotated Bibliography reports on tools which can be used along that road. But adapted tools have still largely to be developed to be able to make progress faster and in the right direction.

Finally, a few important observations on the potential will be illustrated by the work of Midmore (1983a; 1983b; 1984). This author states in one of his publications (Midmore, 1983a): "The potato is not commonly cultivated in mid-elevation and lowland tropics, two regions where approximately one-third of the world's population is concentrated. (...)
Production constraints include high temperatures and periods of excessive humidity or drought. To overcome these constraints, the effects of mulching on increasing potato yields in the hot tropics were investigated. This is a typical example of dissemination of such a well-known traditional technique as mulching. The materials reported to have been successfully used in this
research in Peru are those traditionally applied such as fresh straw (here of barley and rice), rice hulks, mature maize leaves and dried grass leaves, together with (the here unsuccessfully but also traditionally applied) maize stems and sawdust (Comp. also Stigter, 1984d). In this and in another paper with micrometeorological components (Midmore, 1984), also non-traditional material like highly reflective chalk, newspaper and black plastic were researched with the ultimate explicit goal that these last-mentioned manipulations "assist in the interpretation of the beneficial effects of traditional mulching upon potato tuber yield in hot climates". This illustrates an approach that micro-meteorologists can take in quantitative research to help disseminating traditional techniques (Comp. also Stigter et al., 1984a; 1984b).

A next point is that Midmore correctly considers this work to modify in a traditional way the aerial and edaphic environment to favour the growth of potato as a complementary approach to breeding efforts to select clones tolerant to high temperature (Comp. Stigter and Weiss, 1986). He illustrates this for shading (Midmore, 1983b) and draws from the results of this work the conclusion that shading can modify the environment to the extent that potatoes can be grown in hot climates where excess of soil water is not a problem. And extrapolating to new research possible, he concludes: "intercropped potatoes are expected to have less insect and pest damage, and therefore costly inputs could be reduced compared to a monoculture. Vast areas of natural forest, cultivated areas with coconuts, tall fruit crops and intercrop systems with e.g. maize, sorghum, pigeon pea, could be exploited to expand potato cultivation to the hot tropics". These are all traditional techniques or they are based on the principles of such techniques. The mulch paper earlier quoted finishes with: "In summary, mulch is especially beneficial when soil temperatures are high, when precipitation is limited or when a crop does not cover the soil rapidly. In addition to the research in Peru, successful mulching experiments are being conducted in other countries". Then follow three successful IPC-projects on mulch use in the Philippines, Sri Lanka and Rwanda.

The above examples illustrate what micrometeorologists can do by studying traditional techniques of microclimate management and manipulation. Using the extension potential in their conditions, the results will reach the farmer if earlier mentioned organizational and socio-economic conditions are met.

5. ADOPTED RECOMMENDATIONS

The working group adopted the following recommendations:

(i) Considering that the most tradition-bound farmers adopt advisories on farming systems only if they are suited to them in all respects, it is recommended that agrometeorologists understand first the complex farming systems and the circumstances of each different target group of farmers, before issuing weather advisories and other meteorological services addressed to low-input farmers.
(ii) As a basis for such weather advisories, agrometeorologists should study the traditional methods and farming systems which are still practiced and scientifically quantify their results, carrying out experiments and validations of operational techniques wherever possible in the farmers' own fields. This will increase confidence on the part of the farmers and engender better understanding of the traditional agriculture on the part of scientists.

(iii) The traditional techniques employed for microclimate management and manipulation in traditional farming should be tested and validated by CAGM members, in order that these techniques could be transferred to other regions. Such operational techniques should be included in the updated CARS-system for the benefit of advisories for other traditional farmers.

(iv) Agrometeorologists should continue their search for (research results on) techniques for microclimate management and manipulation in traditional farming and their findings should be collected and published, possibly through WMO.

(v) Members should continue to provide case studies on techniques employed for microclimate management and manipulation in traditional farming as well as names of persons/organizations who could furnish information on such techniques, past, present and planned activities, possibly through WMO.

(vi) Members should initiate operational advisory services for microclimate management and manipulation for low-input farmers, making use of validated improved traditional and/or non-traditional techniques. For this purpose they should be able to make use of what is collected as suggested in (iii), (iv) and (v) above.

The above recommendations gave rise to the proposal to either nominate at CAGM IX a rapporteur to monitor and stimulate progress on the subject or to re-establish the working group with renewed terms of reference.
1. During the session of the CAgM Advisory Working Group (Geneva, March 1982), it was suggested that the provisional agenda for CAgM-VIII (see reference 1) should include the item 11.3 – Land use and agricultural management systems under severe climatic conditions. In the report of the first session of the Working Group on Data Requirements for Agriculture, with particular reference to WCP, it was stated that economic problems related to microclimate management and manipulation systems and techniques deserve to be studied before changes in land use and agricultural management are proposed by extension services.

2. Traditional agriculture is practiced by a substantial proportion of the world’s farmers. It has been estimated that half the world’s population depends on a subsistence (mainly traditional) type of agriculture and that 40 per cent of the land area of the world under cultivation is in the hands of the subsistence farmer.

3. Traditional farmers, applying knowledge and techniques that have been derived from individual and social experience, use only locally available energy and materials for environmental management. This is offering a rain-fed, labour intensive agriculture, with low amounts of fertilizing, energy and other inputs involved, and mainly carried out in polyculture on small plots.

4. Farming practices have evolved through centuries or even millennia of experience and have, even though modified by cash crop farming methods, retained indigenous components of microclimate management and manipulation. These practices have often secured survival because they resulted in a low but guaranteed minimum yield under severe climatic and poor soil conditions. They have occasionally, and mostly very locally, even been able to cope with substantial population increases.

5. Examples of manipulation and management of microclimates can be catalogued into four main areas: (a) Manipulation of radiation; (b) Manipulation of heat and/or moisture flow; (c) Manipulation of mechanical impact of wind, rain (water) and/or hail; (d) General examples. They may be altogether subdivided into 45 classes. Appendix A presents this classification.

6. In the ecological situation prevailing under severe climatological and poor soil conditions, any change in agricultural practice to be suggested to the traditional farming community should only be proposed after the acquisition of detailed knowledge of existing farming systems and techniques. This means that more knowledge is required of the ecological balances in the areas concerned and on properties of soil and (micro)-weather and (micro)-climate which determine the agricultural potential of these areas.
7. Further, and especially quantitative, studies of existing largely traditional systems establishing causes and effects are urgently required. The recently chosen approach in, among others, the institutes of the Consultative Group on International Agricultural Research (CGIAR), to concentrate increasingly on "on-farm testing", should incorporate more agrometeorology.

8. Such knowledge can effectively be translated into information and practices suited to specific local conditions and to particular micro-environments.
CATALOGIZATION OF EXAMPLES OF MANIPULATION OF MICROCLIMATE

I. Manipulation of radiation (15 classes) by (A, B, C, D)

A Shading
- 1. using natural means
- 2. using mulch (artificial)
- 3. using artificial means other than mulch

B Increase/Decrease of surface reflectivity or absorption
- 1. reflectivity
- 2. absorption
- 1. use of colour or other surface change
- 2. use of geometry change
- 3. use of stony structures

C Cover for radiation loss at night
- 1. using natural means
- 2. using mulch (artificial)
- 3. using artificial means other than mulch

D Using solar radiation for
- 1. field drying
- 2. keeping products dry in storage
- 3. in the field of growth
- 4. elsewhere before storage

II. Manipulation of heat and/or moisture flow (16 classes) by (E, F, G, H, I, J, K)

E (Non)Tillage

F Mulching
- 1. by natural means
- 2. by artificial means

G 1. Using wind breaks
   2. Using other shelter (storage)

H Protection for ripening purposes

I Influencing flow processes by changing conditions at or on the surface

J Using air warmed by
- 1. solar radiation
- 2. other means
- 1. field drying in the field of growth
- 2. field drying elsewhere before storage
- 3. keeping products dry (and pest free) in storage

K Dew
- 1. increase of
- 2. use of
- 3. protection against natural dew fall
III. Manipulation of mechanical impact of wind, rain and/or hail (12 classes) by (L, M, Q, P, Q)

L Change of
1. direction
2. speed
1. wind
11. other shelter

M Planting in lower places or pits or where deep rooting is possible

N Improving soil conditions by natural deposits

O Protection from soil erosion by
1. wind
2. rain

P Protection of crops and produce against impact by
1. rain
2. hail
3. wind

Q Use of wind for winnowing

IV. Two general examples (R, S)

R Fitting cropping periods to the seasons

S Making use of superhuman intervention
WORKING GROUP ON MICROCLIMATE MANAGEMENT AND MANIPULATION
IN TRADITIONAL FARMING

Res. 14 (CAGM-VIII)

The Commission for Agricultural Meteorology.

Noting:

(1) Doc. 15 (CAGM) - Microclimate management and manipulation in traditional farming,

(2) The report of the first session of the Working Group on Data Requirements for Agriculture with Particular Reference to WCP,

(3) WMO Technical Note No. 136 - Mulching effects on plant climate and yield.

Considering:

(1) The extent to which traditional agriculture is still practiced and the positive economic impact to be expected from judicious changes,

(2) The need to use more specific and quantitative information on existing microclimate management and manipulation techniques in traditional farming especially in severe climatological and poor soil conditions.

Decides:

(1) To appoint a Working Group on Microclimate Management and Manipulation in Traditional Farming, with the following terms of reference:

(a) To assist and encourage Members to collect existing examples of microclimate management and manipulation in traditional farming;

(b) To survey and summarize existing knowledge, as well as research proposals, on microclimate management and manipulation techniques;

(c) To study and summarize the existing general and specific literature on microclimate management and manipulation, to increase the understanding of causes and effects behind empirical traditional knowledge;
APPENDIX II, p. 2

(d) To contact and work in close collaboration with international institutes such as the institutes of the Consultative Group on International Agriculture Research (CGIAR);

(e) To identify potential contributions to CARS-Food;

(f) To submit annually information on progress of activities and a final report to the president of CAGM not later than six months before the next session of the Commission.

(2) To invite the following to serve on the working group:

Prof. C.J. Stigter (United Republic of Tanzania), Chairman
Dr. P.H. Karing (U.S.S.R)
Dr. J. von Hoyningen-Huene (F.R.G.)
An expert to be designated by FAO
An expert to be designated by ICRAF
An expert to be designated by IIIA
An expert to be designated by UNESCO
MICROCLIMATE MANAGEMENT AND MANIPULATION IN TRADITIONAL FARMING

Rec. 3 (CAGM-VIII)

The Commission for Agricultural Meteorology,

Noting:

(1) Doc. 15 (CAGM-VIII) - Microclimate management and manipulation in traditional farming.

(2) The report of the Working Group on Data Requirements for Agriculture with Particular Reference to WCP.

(3) WMO Technical Note No. 136 - Mulching effects on plant climate and yield.

Considering:

(1) The extent to which traditional agriculture is still practiced and the positive economic impact to be expected from judicious changes.

(2) The need to use specific and quantitative information on existing microclimate management and manipulation techniques in traditional farming especially in severe climatological and poor conditions.

Recommends that Members be urged:

(1) To collect and apply information on such techniques,

(2) To encourage research on such techniques.
LIST OF MEMBERS OF THE WORKING GROUP

Dr. T. Darnhofer
ICRAF
P.O.Box 30677
NAIROBI
KENYA

Mr. L.B. Garay (resigned 1984)
Director General Aeronautica Civil
Aer. Intern. "Toncontin"
A.T-245
TEGUCIGALPA D.C.
HONDURAS

Dr. P.H. Karing
c/o Permanent Representative of USSR
with WMO
USSR State Comm. Hydrometeor.
12 Pavlik Morozov Street
123376 MOSCOW D-376
USSR

Dr. T.D. Lawson
IITA
P.M.B. 5320
Oyo Road
IBADAN
NIGERIA

Mr. G.F. Popov
FAO
AGP Division
Via delle Terme di Caracalla
00100 ROME
ITALY

Prof. C.J. Stigter (Chairman)
till 1/10/84
University Dar es Salaam
Physics Department
P.O.Box 35063
DAR ES SALAAM
TANZANIA

afterwards
Agricultural University
Dept. Physics Meteor.
Duivendaal 1
6701 AP HAGENINGEN
THE NETHERLANDS
Dr. J. Von Hoyningen-Huene
Deutscher Wetterdienst
St. Bundesallee 50
3300 BRAUNSCHWEIG
F.R. GERMANY
APPENDIX IV b

LIST OF CORRESPONDENTS OR FORMAL CONTACT PERSONS WITH THE CAHM WORKING GROUP ON "MICROCLIMATE MANAGEMENT AND MANIPULATION IN TRADITIONAL FARMING"

Dr. J.P. Andriesse
Royal Tropical Institute, The Netherlands

Mr. L. Daisley
Caribbean Agricultural Research and Development Institute

Dr. F. Duhme
International Union for the Conservation of Nature and Natural Resources

Mr. G. Gryseels
International Livestock Center for Africa

Dr. P. Hazell
International Food Policy Research Institute

Dr. P.C. Jones
Centro Internacional de Agricultura Tropical

Dr. D. Keatinge
International Center for Agricultural Research in the Dry Areas

Dr. D. J. Midmore
International Potato Center

Dr. L.R. Oldeman
International Rice Research Institute

Mr. C. Samie
Institut National de Recherche Agricole, France

Mr. P.E.O. Usher
United Nations Environment Programme
CATALOGIZATION OF EXAMPLES OF MANIPULATION OF MICROCLIMATE

I. Manipulation of radiation (15 classes) by (A, B, C, D)

A Shading
   1. using natural means
   2. using mulch (artificial)
   3. using artificial means other than mulch

B Increase or decrease of surface (1. reflectivity)
   i. use of colour or other surface change
   ii. use of geometry change
   iii. use of stony structures

   (2. absorption )

C Cover for radiation loss at night
   1. using natural means
   2. using mulch (artificial)
   3. using artificial means other than mulch

D Using solar radiation for
   1. field drying...
      i. in the field of growth
      ii. elsewhere before storage
   2. keeping products dry in storage
II. Manipulation of heat and/or moisture flow (16 classes) by (E, F, G, H, I, J, K)

E   (Non)Tillage

F   Mulching
    1. by natural means
    2. by artificial means
        1. Using wind breaks

G   2. Using other shelter (storage)

H   Protection for ripening purposes

I   Influencing flow processes by changing conditions at or on the surface
    1. solar radiation)  
        i. field drying in the field of growth
    2. other means  )  
        ii. field drying elsewhere before storage
        iii. keeping products dry (and pest free) in storage

J   Using air warmed by
    1. Increase of
    2. Use of  ) natural dew fall
    3. Protection against

K   Dew
III. Manipulation of mechanical impact of wind, rain and/or hail (12 classes) by (L, M, O, P, Q)

L  
1. direction)  
2. speed  
   ) of wind and air flow by  
i. wind breaks  
   ii. other shelter

M  
Planting in lower places or pits or where deep rooting is possible

N  
Improving soil conditions by natural deposits

O  
Protection from soil erosion by  
1. wind  
2. rain an hail

P  
Protection of crops and produce against impact by  
1. rain  
2. hail  
3. wind

Q  
Use of wind for winnowing

IV. Two general examples (R, S)

R  
Fitting cropping periods to the seasons

S  
Making use of superhuman intervention
APPENDIX V b

EXTRACT FROM THE ANNUAL PROGRESS REPORT
SUBMITTED TO THE PRESIDENT OF CAGM

Taking out 15 answers (33%) from Members who indicated that no material on the subject or related subjects is available with them, the remaining 31 answers may be distributed over the following five categories:

(a) Seven developed countries indicated, be it in most cases extremely concisely, existence of some work in their country which could be assessed as related studies which may contribute to scientific understanding of traditional techniques still practised. We had to take action to get more actual information on this work as no details were provided in any of these cases.

(b) In the case of three developing countries, only agrometeorological parameters were measured without any management and/or manipulation being involved.

(c) In three more cases largely management and manipulation, methods were applied using non-local materials and methods, which may, in some examples but not all, be of methodological interest, but belong in general to category a. These methods are as such too expensive to replace traditional methods in low-input agriculture.

(d) In nine regionally distributed cases (five in Africa, two in Latin America, one in the Middle East and one in Asia/Pacific), the existence of traditional practices in our field of work was (often abundantly) indicated, but written information (reports, studies, projects etc.) were not (yet) available.

(e) This leaves nine countries, regionally distributed as two in Europe, two in Africa, and five in Asia/Pacific which supplied published examples of the actual information we were after. For France and the Federal Republic of Germany, the examples were partly of categories a. and c. but for an important part of the work carried out in collaborative development projects within and/or with developing countries. It is rather disappointing that several other developed countries of which we know that they carry out such projects on a large scale have not supplied any information on these undertakings. Of the African examples, in fact one, that of Tanzania, falls basically under the latter category as all information was collected in such a project financed by the Netherlands. This leaves Nigeria as the exceptional example from Africa in which published information was available in the country's institutions. Thus, it could be concluded that most published information through the questionnaire came from the remaining countries: China, Japan, Malaysia, Indonesia and Papua New Guinea, all in the Asian/Pacific region.
On a regional basis the discussions could be concluded as follows:

Africa

The exceptional position of Nigeria must be due to the relatively very high attention being paid in that country to Agricultural Research and Education, strengthened by the (not accidental) presence of one of the International Agricultural Research Institutes. Most examples of traditional techniques still in use but not studied and published are presented from Africa. It remains therefore extremely difficult to assess to what extent traditional knowledge is really taken seriously within African research and extension. The Tanzanian experience indicates a very low amount of agricultural research in general and of operational agrometeorology in particular. On traditional agricultural techniques not much is done either. Moreover agricultural extension, as far as it exists, is not very instrumental in the actual peasant mode of production. We are afraid that this applies to large parts of Africa South of the Sahara. Surprisingly, the replies to the questionnaires from all of Northern Africa are absent. However, what is said below for the Middle East may partly apply there as well, although other sources hold more examples from the former than from the latter.

Middle East

Middle-Eastern replies are almost absent. In dry farming regions with insufficient rainfall, management and manipulation of water is much more important than that of microclimate, although several of the classes of our cataloguing, especially those of the mechanical impacts, may be important in this respect. However, ancient methods of water use have left their traces. They can be studied and related to still existing traditional methods. This does not apply to microclimatic modification techniques. Even the "dew-mounds" of the Negev after all appeared to be part of a run-off manipulation system. From semi-arid areas of the Middle-East, which are much less extensive than the arid ones, no information on traditional techniques has been received. It is therefore not clear whether or not such techniques are still in use.

Asia/Pacific

The fact that especially the post-war research of the fifties in Japan appears relevant to our field of work springs from the local micrometeorological tradition and the need at that time for an agricultural intensification with initially relatively simple means and the use of a lot of cheap labour. Only slowly in the course of the sixties, and more intensively in the seventies, agricultural microclimate management has shifted its emphasis to controlled greenhouse conditions. These are therefore less relevant to our undertaking. As has already been shown in earlier reviews on traditional microclimate manipulation and management, the older Japanese literature, which has been made more accessible in the mid-seventies but would benefit from an even higher accessibility for the sake of technology transfer, is excellent in reporting and in quantifying traditional agricultural field conditions with relatively simple instrumentation and a high degree of actual
understanding. Making use of our increased knowledge, this approach in the application of micrometeorology to agriculture could be followed with a comparable success in the Third World of today. It is most likely not accidental that a relative amount of published contemporary material came from other parts of the Asia/Pacific region. The main gain from our questionnaire is that it has shown that many examples exist there as well, although such methods have been explicitly studied only in a limited number of cases (but more than in Africa), especially with respect to aspects of soil conservation and agroforestry.

Latin-America

The preoccupation with cash-crop farming and large scale agriculture in the agricultural research in Latin-America may be the main reason for the fact that no published examples were received from that part of the world. Only in two cases indications were given of the existence of examples. We have collected more abundant evidence, however, from other sources that still large groups of small farmers exist in that region which apply traditional methods of microclimate management and manipulation in low-input agriculture.
"What is wanted is a system to integrate and consolidate what is already known in the tropical scientific and folklore community at large, and get it operating in the context of sustained-yield agro-ecosystems".

Daniel H. Janzen
in: Ecology of Plants in the Tropics, 1975
NOTE

Case Studies – Published

Thirty-five case studies are presented. Examples similar to these should be collected (readers are requested to fill in tear-out sheets attached at the end of this report). The list contains examples of two kinds:

1. Micrometeorological studies (quantitative, experimental) of traditional techniques of microclimate management and manipulation.

2. Micrometeorological studies (idem) made deliberately to increase experience on application of such techniques.

They are classified as per the cataloguing reproduced in Appendix I (see also Stigter and Weiss, 1986). They are summarized in one or two sentences. It is indicated when and where the results were reported. The names and addresses for further information are given as far as they could be traced. If the names are mentioned in the references of Appendix VI, published information can be retrieved.

Case Studies – Planned and Ongoing Projects

Of these 20 Case Studies, ten are taken from the questionnaire replies and ten from other sources. The collection of similar examples should continue (again through the tear-out sheets at the end of this report). The kinds of examples used are the same in both cases. Classification is also identical. It is indicated where and by whom (investigators) these projects are carried out.

References for a selectively annotated Bibliography

With the continuation of the collection of examples of published Case Studies and Planned and On-going Projects Case Studies, it is also proposed to compile a selectively annotated Bibliography. In Appendix IVc, more than 100 references are given which are suitable for inclusion in such a Bibliography. They are of three different kinds:

(i) Descriptive reviews of traditional techniques of microclimate management and manipulation:

(ii) Important descriptive case studies of such techniques (for example as part of longer articles on traditional agro-ecosystems);

(iii) Important basic micrometeorological review literature which deals with management and/or modification of microclimates and can be used for giving a micrometeorological basis to such traditional techniques.
The selected references are classified according to the system used (capital letters A to R) for cataloguing in Appendix I or with a remark "All", where the reference is a more general micrometeorological background study.

There is an acute need for further examples of studies like the ones given in the report. It is sufficient if the readers supply the reference and addresses from whom further information could be obtained. The annotations need not be done by the readers themselves (see tear-out sheets at the end of this Final Report). By selectively annotated we mean annotated on aspects of traditional techniques in our fields of interest and/or on a micrometeorological basis for understanding such techniques. It is proposed to up-date and publish the selectively annotated bibliography, drawing upon the work of the rapporteurs nominated under Resolution 3 of CAgM-IX (Rapporteurs on the Application of Microclimate Management and Manipulation Techniques in Low External Input Agriculture).
APPENDIX VI a

CASE STUDIES – PUBLISHED

A1

Light transmission under smallholder coconut plantations as a function of stand age, density and height.

Reported in 1982, Malaita, Solomon Islands.
Address: Dr. T. Litscher, Department of Agriculture, University of Queensland, St. Lucia Q4067, Australia.

A1

Light transmission of various crop mixtures to determine their efficiency in controlling weed growth by their shade.
Address: T.L. Lawson, IITA-Benin, BP 06-2523 Cotonou, Rep. Pop. du Benin or
Dr. B.T. Kang, IITA, Box 5320, Ibadan, Nigeria

A1

Light transmission and cassava and maize yields in maize/cassava mixtures of different geometry and densities to provide a basis for optimal design in mixed cropping systems and patterns.
Address: T.L. Lawson, IITA-Benin, BP 06-2523 Cotonou, Rep. Pop. du Benin or
Dr. B.T. Kang, IITA, Box 5320, Ibadan, Nigeria

A1

Comparison of two cassava/cowpea mixtures, with two cassava varieties with different leaf properties, with respect to cowpea yield differences due to light transmission.
Annual report of 1982, pp. 144 and 145.
Address: T.L. Lawson, IITA-Benin, BP 06-2523 Cotonou, Rep. Pop. du Benin or
Dr. B.T. Kang, IITA, Box 5320, Ibadan, Nigeria

A1 + A2 + E + I + O2

Soil moisture conditions under different live mulches grown with crops to prevent soil erosion, to control weeds and to maintain productivity, under conventional and no-till conditions.
Address: T.L. Lawson, IITA-Benin, BP 06-2523 Cotonou, Rep. Pop. du Benin or
Dr. B.T. Kang, IITA, Box 5320, Ibadan, Nigeria
**APPENDIX VI a. p. 2**

**A1 + A3**

Potato production under shade from intercropping with maize and coconuts as a beneficial modification of the micro-environment in the warm tropics.


Address: Dr. D.J. Midmore, International Potato Center, Apartado 5969, Lima, Peru.

**A1 + A2**

Radiation as a function of crop and shrub heights and the difference between shrub row and first crop row in alley cropping systems, with four different shrub species, two different spacings and maize and cowpeas as crops, for one row orientation.


Address: T.L. Lawson, IITA-Benin, BP 06-2523 Cotonou, Rep. Pop. du Benin or Dr. B.T. Kang, IITA, Box 5320, Ibadan, Nigeria

**A1 + B2i**

Light transmission of nine tropical plant communities including monocultures, natural and planted low-diversity and high-diversity polycultures.

Annual Report of: 1982, Costa Rica and Mexico, by Department of Botany, University of Florida + Colegio Superior de Agricultura Tropical (Mexico) + CATIE (Costa Rica).

Address: Dr. J. Ewel, Department of Botany, University of Florida, Gainesville, FL 32611, USA.

**A1 + B2ii**

Light transmission of maize in different planting geometry (and densities) with the aim of gaining light (yield) for an intercrop.


Address: T.L. Lawson, IITA-Benin, BP 06-2523 Cotonou, Rep. Pop. du Benin or Dr. B.T. Kang, IITA, Box 5320, Ibadan, Nigeria

**A1 + J**

Radiation and soil moisture in maize/cassava and cassava/weed mixtures where leaf angle distribution and leaf surface density of maize (in the first case) and cassava (in the second case) differ.


Address: T.L. Lawson, IITA-Benin, BP 06-2523 Cotonou, Rep. Pop. du Benin or Dr. B.T. Kang, IITA, Box 5320, Ibadan, Nigeria
A2
Shading properties of traditionally applied dry grass mulch layers.
Reported in: 1984/85, Agricultural Physics Section, University of Dar es Salaam, Tanzania
Address: Prof. C.J. Stigter, Agricultural University. Department of Physics and Meteorology, Duivendaal 1, 6701 AP, Wageningen, The Netherlands.

A2 + F2
Micrometeorological study on the effect of traditional straw-matting (straw mulching) on ground surface temperature.
Reported in: 1952, Memoirs of Industrial Meteorology (Japan).
Address: not given. Authors: Y. Daigo and E. Maruyama.

A2 + F2
The use of traditional mulches for introducing growth of potatoes in the hot tropics and the use of non-traditional mulches to assist in the interpretation of the beneficial effects of traditional ones (soil temperature, reflectivity of radiation and light measurements).
Address: Dr. D.J. Midmore, International Potato Center. Apartado 5969, Lima (Peru).

B2ii
Experiments on staircase-like sloping beds used by traditional farmers to have early strawberries. Measurements of air temperature, soil temperature, solar radiation absorption.
Reported in: 1957, Memoirs of Industrial Meteorology (Japan)

B2ii
Light interception in bean-maize intercropping under increasing competition for light of maize in a developing bean crop (to increase understanding of traditional intercropping systems).
Reported in: 1982. Work at the Department of plant and soil science, University of Massachusetts.
Address: Dr. T.R. Gardiner, Centro Pasa Potencial Humans. La Guacimo, Alajuela, Costa Rica.

B2ii + I
Experiments with traditional and other forms of seed-beds and ridgefarming (on temperature and subsequent wheat growth).
Address: S. Hara, Kanagawa Crop Report Office, Japan. Journal: The Faculty of Agriculture, University of Tokyo, 1--1-1, Yayoi, Bunkyo-ku, Tokyo, Japan.
APPENDIX VI a, p. 4

B2ii + I
Effects on microclimate of traditional and mechanical clearing of a tropical forest (soil temperature, air temperature and humidity, post clearing management).
Address: Dr. R. Lal, International Institute of Tropical Agriculture, P.O.Box 5320, Ibadan, Nigeria.

B2ii + I
Leaf water potentials and light transmission of intercropped sorghum and soyabean (to increase understanding of traditional intercropping systems).
Address: Dr. T.A.T. Wakwa, Department of Agronomy, University of Ibadan, Nigeria.

F2
Thermal efficiency of artificial inorganic mulches (to assist in explaining traditional techniques of mulching).
Address: Prof. C.J. Stigter, Agricultural University, Department of Physics and Meteorology, Duivendaal 1, 6701 AP Wageningen, The Netherlands

F2
Thermal efficiency of traditional dry and live organic mulches (grass). Applications to tea growing and general.
Address: Prof. C.J. Stigter, Agricultural University, Department of Physics and Meteorology, Duivendaal 1, 6701 AP Wageningen, The Netherlands

F2 + C2 + I
Examples of exploration by traditional mountain farmers in Nepal of the limiting factor of (soil, air and water) temperature as a local resource in rice and maize growing.
Address: Dr. P.T.S. Whiteman, FAO Integrated Rural Development, P.O.Box 1476, Islamabad, Pakistan.
**G1**

The effects of wind break used by some traditional farmers to raise rice bed water temperature.

Address: T. Asai, Research Institute for Natural Resources.
Journal: The Faculty of Agriculture, University of Tokyo, 1-1-1, Yayoi, Bunkyo-ku, Tokyo, Japan.

**G1**

Increase of irrigation efficiency by means of traditional dry palmleaves windbreaks in an arid oasis with advective stress in Saudi Arabia (measurements of wind speed, water use, yields).

Address: Dr. F.C. Brandner, Leichtweiss-institut für Wasserbau, Technische Universität Braunschweig.

**G2 + Jlili**

Improvements in maize storage (airflow management, moisture migration due to exposure/shading) for the smallholder farmer.

Address: Dr. F. Golob, Storage Department, Tropical Development Research Institute, Slough, U.K.

**I**

Temperature and moisture in unstabilized dunes under traditional land use for melon growth and perspectives of diversification (under erosion preventive conditions).

Reported in: 1976. *Work in Western Rajasthan by CAZRI.*
Address: Dr. H.S. Mann, Central Arid Zone Research Institute, Jodhpur, India.

**I**

Soil moisture conditions under various crop mixtures with and without weeds.


**I**

Soil moisture conditions and soil temperatures in maize/cassava mixtures of different geometry and densities.

I

Soil moisture conditions under different shrub/crop combinations and as a function of distance to the shrub row in alley cropping systems, with four different shrub species, two different spacings and maize and cowpeas as crops.

Address: T.I. Lawson, IITA-Benin, BP 06-2523 Cotonou, Rep. Pop. du Benin or
Dr. B.T. Kang, IITA, Box 5320, Ibadan, Nigeria

L21

On the role of bambooblades as a windbreak often used by farmers to protect crops (speed and temperature).

Address: E. Maruyama and Y. Yamamoto, Central Meteorological Observatory.
Journal: The faculty of Agriculture, University of Tokyo, 1-1-1, Yayoi, Bunkyo-ku, Tokyo, Japan.

L22

On the straw fence (ordinary and around the field) often used by farmers as a windbreak to protect crops from wind damage (speed and dust).

Address: Y. Daigo and E. Maruyama, Central Meteorological Observatory.
Journal: The faculty of Agriculture, University of Tokyo, 1-1-1, Yayoi, Bunkyo-ku, Tokyo, Japan.

L23

On the effects of shelter-hedge at two sides of an upland rice field against typhoon (artificial plantings to assist in explaining and improve on traditional protection).

Address: M. Kawamata, Y. Tsukilima and T. Sato, Kanoya Farm, Division of Kagoshima Prefectural Agricultural Experiment Station.
Journal: The faculty of Agriculture, University of Tokyo, 1-1-1, Yayoi, Bunkyo-ku, Tokyo, Japan.

01

Winderosion-prevention by catch ditch of flying soil.

Address: S. Tanaka, H. Sano, T. Takizawa and S. Kakinuma, Kanto-Tosan Agricultural Experiment Station.
Journal: The faculty of Agriculture, University of Tokyo, 1-1-1, Yayoi, Bunkyo-ku, Tokyo, Japan.
O1 + L21

Effect of Kittatemaki (ridged traditional no-tillage with stubbles) on the control of wind-erosion (wind speed, surface soil moisture, flying soil).
Address: S. Tanaka, H. Sano, T. Takizawa and S. Kodera, Kanto-Tosan Agricultural Experiment Station.
Journal: The faculty of Agriculture, University of Tokyo, 1-1-1, Yayoi, Bunkyo-ku, Tokyo, Japan.

R

Traditional forecasting of tropical rainy seasons in Tanzania linked to local agricultural decision-making processes.
Address: Dr. I. J. Jackson, Department of Geography, University of New England, Armidale, N.S.W. 2351, Australia.

R

The influence of different variable precipitation regimes on the management of three-course crop rotations at three selected sites in one ecological zone.
Address: Dr. J. D. H. Keatinge, International Center for Agricultural Research in the Dry Areas, Box 5466, Aleppo, Syria.
Mihara, Y. (Ed.), 1975
Agricultural Meteorology of Japan.
University of Tokyo Press, Tokyo, Japan.

Mischenko, Z.A. (Head of Ed.), 1985
Climatic and microclimatic research in Moldavia.
Shtiintsa, Kishinev, USSR.

Monteith, J.L. (Ed.), 1975, 2 volumes

Oebker, N.F. and Hopen, H.J., 1974
Microclimate modification and the vegetable crop ecosystem.

On the use of Stigter's ratio in expressing the thermal efficiency of grass mulches.

Multiple cropping.
ASA Special Publication 27, Madison (WI, USA).

Radke, J.A. and Hagstrom, R.T., 1975
Strip intercropping for wind protection.
In: R.A. Papendick et al. (Eds.), Multiple cropping. ASA, Madison (WI, USA).

Rauner, Y.L., 1960
Formation mechanism of the heat balance and microclimate in arid zones.
Academy of Sciences, Moscow, USSR.
Romanova, E.N., 1977
The microclimatic variability of the main climatic elements.
Gidrometeoiizdat, Leningrad, USSR.

Romanova, E.N., Beresneva, I.A. and Nikolaeva, Z.I., 1981
Recommendations for the assessment of microclimate resources of the
non-black soil zone of the RSFSR.
Moscow Branch of Gidrometeoiizdat, Moscow, USSR.

Romanova, E.N., Mosolova, G.I. and Beresneva, I.A., 1983
Microclimatology and its implications for agriculture.
Gidrometeoiizdat, Leningrad, USSR.

Rosenberg, N.J., 1967
The influence and implication of windbreaks on agriculture in dry regions.
In: Ground level climatology, AAS, USA.

Microclimate: the biological environment.
Wiley & Sons, New York, USA.

Sapozhnikova, S.A., 1950
Microclimate and local climate.
Gidrometeoiizdat, Leningrad, USSR.

Savage, M.J., 1980
The effect of fire on the grassland microclimate.
Nr. 12: 589-603.

Schwerdtfeger, P., Radok, U., Bennett, J., (A, B, I, L)
Van Meurs, B., Piggot, I., Ussher, A. and Wu, A., 1975
The micrometeorology of the plant environment.
In: L.P. Smith (ed.): The effect of weather and climate on plants.
Swets & Zeitlinger, Amsterdam, The Netherlands.

Schwerdtfeger, P., 1976 (B, I, L)
Physical principles of micrometeorological measurements.
Elsevier, Amsterdam, The Netherlands.

Shebeko, V.F., 1977
Microclimatic change induced by marshland drainage.
Nauka i technika, Minsk, USSR.
Shulgin, A.M., 1972
Soil climate and soil climate control.
Gidrometeoizdat, Leningrad, USSR

Smith, L.P., 1975
("ALL")
Methods in agricultural meteorology.
Elsevier, Amsterdam, The Netherlands.

Stigter, C.J., 1982a
("ALL")
Manipulation of microclimate in Tanzanian traditional farming:
a preliminary contest report.
In: C.J. Stigter (Ed.), NAC-Tanzania Newsletter Nr. 7, Directorate of
Meteorology, Dar es Salaam, Tanzania.

Stigter, C.J., 1984b and 1984c
(A, B, C, D, I, O, P)
Shading, a traditional method of microclimate management and Traditional

Stigter, C.J., 1984d and 1984e
(A, C, E, F, I, N,
management and Examples of mulch use in microclimate management by
traditional farmers in Tanzania.
Environn. 11: 173-176.

Stigter, C.J., Mwampaaja, A.R.
and Kainkwa, R.M.R., 1984a
(A, C, F)
Infrared surface and thermistor sub-surface temperatures explaining the
thermophysical character of grass mulches.

Stigter, C.J., Othieno, C.O.
and Mwampaaja, A.R., 1984b
(A, F, O)
An interpretation of temperature patterns under mulched tea at Kericho,
Kenya.
Agric. For. Meteorol. 31: 231-239.

Stigter, C.J., Mjungu, Y.B., Lutege, P.B.M.,
(A, B)
Relationships between soil albedos and soil and air temperatures.
Neth. J. Agric. Sc. 32: 33-42.
Stigter, C.J., 1985a and 1985c (*"ALL"")

Stigter, C.J., 1985d (*A. F. I. O*)

Stigter, C.J., 1985e (*G. L. M. N. O. P. Q*)

Stigter, C.J., 1985f (*"ALL"*)
Modification of surface properties as traditional manipulation of microclimates. In: M.T. Jiwoji and C.B.S. Usis (Eds.), NAC-Tanzania Newsletter No. 12, Directorate of Meteorology, Dar es Salaam, Tanzania.

Stigter, C.J., 1985g (*"ALL"*)
Research methodology to quantify and understand the modification of the energy flux at soil/atmosphere interfaces. Proceedings of the International Colloquium on Energy Flux at the Soil/Atmosphere Interface, International Centre for Theoretical Physics, Trieste (Italy), 16 pp.

Stigter, C.J. and Weiss, A., 1986 (*"ALL"*)

Stoutjesdijk, Ph., 1977 and 1980 (*A. B. I*)
Sturrock, J.W., 1975a
Wind effects and their amelioration in crop production.
In: U.S. Gupta (Ed.). Physiological aspects of dryland farming, Oxford
& IBH Publ. Co., New Delhi, India.

Sturrock, J.W., 1975b
The control of wind in crop production.
In: L.P. Smith (Ed.). The effect of weather and climate on plants, Div.
The Netherlands.

Tanner, C.B., 1974
Microclimate modification: basic concepts.

Tooming, H.G. and Karing, P.H. (Eds.), 1981
Simulation of crop production and microclimate.
Proc. VNIISSH, Issue 2, Gidrometeoizdat Leningrad, USSR.

Tsipris, D.B. and Revut, V.I., 1974
Irrigation and mulching in the European North-West of the USSR.
Gidrometeoizdat, Leningrad, USSR.

Conservation tillage systems.

Waggoner, P.E., (Ed.), 1965
Agricultural meteorology.

Computer techniques and meteorological data applied to problems of
agriculture and forestry: A Workshop.
National Science Foundation, Anaheim (CA, USA).

Wilken, G.C., 1972
Microclimate management by traditional farmers.

Williams, C.N. and Joseph, K.T., 1970
Climate, soil and crop production in the humid tropics.
Oxford University Press, Kuala Lumpur, Malaysia.
Wood, A. and Humphreys, G.S., 1982
Traditional soil conservation in Papua New Guinea.
In: L. Moraute et al (Eds.), Traditional conservation in Papua New Guinea: Implications for today.

Woodhead, T., 1968 and 1969
Micrometeorological studies of coffee berry disease and An investigation into some micrometeorological aspects of coffee berry disease.

Wijk, W.R. van and De Wilde, J., 1962
Microclimate.

Wijk, W.R. van (Ed.), 1966 (2nd Ed.)
Physics of plant environment.
APPENDIX VI

Guyot, G., 1980
L’Érosion éolienne.

Hatfield, J.L., 1982
Modification of the microclimate via management.

Henricksen, B.L. and Durkin, J.W., 1985
Moisture availability, cropping period and the prospects for early warning of famine in Ethiopia.

Hewitt, K. (Ed.), 1983
Interpretations of calamity
Allen & Unwin Inc., Boston, USA.

Hillel, D. (Ed.), 1972
Optimizing the soil physical environment toward greater crop yields.
Academic Press Inc., New York, USA.

Holzberg, I.A., (Ed.), 1967
Microclimate of the USSR.
Gidrometeoizdat, Leningrad, USSR.

Holzberg, I.A. and Davitaya, F.F. (Eds.), 1971
Soil climate. Collection of papers presented at the meeting of the scientific council for studies of climatic and agroclimatic resources.
Gidrometeoizdat, Leningrad, USSR.

Hoyningen-Huene, J. von, 1980
Mikrometeorologische Untersuchungen zur Evapotranspiration von Bewässerten Pflanzenbeständen.
Berichte des Instituts für Meteorologie und Klimatologie der Universität Hannover, Nr. 19.

Hoyningen-Huene, J. von, 1985
Mikroklimatische Bedingungen für die Agrarproduktion in Al Hassa:
a) Wärme- und Wasserhaushalt von Kulturpflanzen.
Leichtweiss-Institut für Wasserbau der Technischen Universität Braunschweig, Mitteilungen, Heft 84: 175-227.
Fuchs, M., 1979
Atmospheric transport processes above arid-land vegetation.
In: R.A. Perry and D.W. Goodall (Eds.), Arid-land Eco-systems:
structure, functioning and management, Vol. I, Cambridge University

Geiger, R., 1961
(4th Ed., translation from German)
The climate near the ground.
Harvard University Press, Cambridge (MA, USA).

Gerber, J.F., Martsolf, J.D.
and Bartholic, J.F., 1974
The climate of trees and vines.

Grace, J., 1977
Plant response to wind.

Grace, J., Ford, E.D.
and Jarvis, P. G. (Eds), 1981
Plants and their atmospheric environment.

Grace, J. (Ed), 1985
Effects of shelter on the physiology of plants and animals.
Progress in Biometeorology, Vol. 2. Swets & Zeitlinger, Lisse,
The Netherlands.

Grolleaud, M. 1985
Granary styles as a reflection of culture and climate.
Ceres, FAO review 18. Nr. 106: 4-5.

Guyot, G., 1963
Modification des microclimats et amélioration de la production agricole.
In: L'eau et la production végétale, INRA, Paris, France.

Guyot, G., et al., 1975
Climats, agriculture et aménagement en pays de bocage.
Géomètres: 11-78.
APPENDIX VI c, p. 2

Budyko, M.I., 1974
Climate and Life.
Gidrometeozdat, Leningrad, USSR

Darmhofer, T., 1983
Microclimatic effects and design considerations of shelterbelts.
In: D.A. Hoekstra and F.M. Kuguru (Eds.), Agroforestry systems for small-scale farmers, ICRAF (Nairobi, Kenya).

Davies, J.W., 1975a
Mulching effects on plant climate and yield.
WMO-No. 388 (Techn. Note No. 135), Geneva, Switzerland.

Davies, J.W., 1975b
The control of soil climate by mulching.

Eddy, A., 1983
Beneficial uses of climate.
WCP 39, WMO, Geneva, Switzerland.

Eimern, J. van et al., 1964
Windbreaks and shelterbelts.
WMO No. 147 TP 70 (Techn. Note No. 59), Geneva, Switzerland.

Fournier d'Albe, E.M., 1958
The modification of microclimates.

Fuchs, M. 1972
The control of the radiation climate of plant communities.
In: D. Hillel (Ed.), Optimizing the soil physical environment toward greater crop yields. Academic Press, New York, USA.
REFERENCES FOR A SELECTIVELY ANNOTATED BIBLIOGRAPHY
ON ASPECTS OF TRADITIONAL TECHNIQUES OF MICROCLIMATE MANAGEMENT
AND MANIPULATION OR ON A MICROMETEOROLOGICAL BASIS
FOR UNDERSTANDING SUCH TECHNIQUES

Adamenko, V.K., 1979
Microclimatology in land improvement.
Gidrometeoizdat, Leningrad, USSR.

Allan, W., 1965
The African Husbandman.
Oliver and Boyd, Edinburgh (repr. 1977, Greenwood Press, Westport), UK.

Radiation and microclimate relationships in multiple cropping systems.
In: R.I. Fapendick et al. (Eds.), Multiple cropping. ASA, Madison (USA): 171-200.

Altieri, M.A., 1983
Agroecology: The scientific basis of alternative agriculture. University of California Press, Berkeley, USA.

Anonymous, 1974
The regimes of moisture supply and improvement of moisture conditions in the steppes.
Koios, Moscow, USSR

Arkin, C.F. and Taylor, H.M. (Eds.), 1981
Modifying the root environment to reduce crop stress.
ASAE Mon. 4, St. Joseph (MI, USA).

Baldy, C., 1963
Cultures associées et productivité de l'eau.
In: L'eau et la production végétale, INRA, Paris, France.

Baldy, C., 1985
Contribution à l'étude des applications de la bioclimatologie végétale à l'agrométéorologie des zones arides et semi-arides en climats méditerranéen et tropical.
Thèse de Docteur es-Sciences, Université de Droit, d'Economie et des Sciences d'Aix-Marseille, France.

Barfield, B.J. and Gerber, J.F. (Eds.), 1979
Modification of the aerial environment of plants.
ASAE Mon. 2, St. Joseph (MI, USA).

Beets, W.C., 1982
Multiple cropping and tropical farming systems.
Gower and Westview Press, Aldershot (England) and Boulder (CO, USA).
L2i + O1
Installation of wind breaks around parts of a gravity irrigation system recently installed, to modify the depositing of sand.
Carried out in the Tihama area, North Yemen.
Investigators: unknown.

L2i + O1
Windbreak plantings to protect irrigated plots at the Nile borders against encroachment by wind blown sand in the Nubian desert (Kerma basin).
Carried out in the Sudan.
Investigators: Station de Bioclimatologie (INRA, Montfavet, France) (Dr. Guyot) and local people.

C1
A generalized study on soil erosion and an evaluation of traditional soil conservation techniques in the central highlands of Papua New Guinea.
Carried out in Papua New Guinea.
Investigators: Department of Geography, University of Papua New Guinea, Papua New Guinea, Dr. G.S. Humphreys and local people.

R
Serial sowing trials with pulses, grains and root crops.
Carried out in Fiji.
Investigators: Research Division, Department of Agriculture, Ministry of Primary Industries, P.O.Box 77, Nauro, Fiji.
Details to be obtained from the Annual Research Reports of that Research Division (Dr. P. Shivan, Assistant Director of Agriculture (Research)).

"Several"
Developing techniques for preventing further degradation of the resource base of small farmers in low-rainfall areas.
Carried out in Syria.
Investigators: International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria (including local people).
Crop coefficients in water use of food crops under traditional and changed irrigation practices in the Gezira Scheme, the Sudan.
Carried out in the Sudan.
Investigators: Department of Environmental Sciences and Natural Resources, University of Gezira, Wad Medani, the Sudan (Dr. H.S. Adam, with collaboration of Hydraulics Research Station, Wad Medani and Gezira University Department of Agricultural Engineering) and T.T.M.I.-project, Department of Physics and Meteorology, Agricultural University, Wageningen, The Netherlands (Prof. C.J. Stigter).

Protection of coffee plantations from strong winds by windbreaks. Although there are already regions with windbreaks, their optimum design will be investigated in order to achieve maximum protection for the crop at minimum cost.
To be carried out in El Salvador: in the South of the departments of Santa Ana and Ahuachapin and the North of Sonsonate.
Investigators: Meteorological and Hydrological Service of El Salvador (Dr. G.T. Guzmán).

A study on the meteorological factors causing wind damage of crops (vertical and horizontal wind speed distribution in the ratio of open wind speed to the windward and leeward of windbreaks: net and reed mat).
Carried out in Korea.
Investigators: Meteorological Research Institute, Central Meteorological Office, Seoul, Korea.

Wind protection in traditional farming in Tanzania.
Carried out in Tanzania, financed by Dutch Government.
Investigators: Agricultural Physics Section, Physics Department, University of Dar es Salaam, Tanzania (Mr. R.M.R. Kainkwa, M. Sc.) and T.T.M.I.-Project, Department of Physics and Meteorology, Agricultural University of Wageningen, The Netherlands (Prof. C.J. Stigter).

Trials to establish artificial windbreaks allowing a progressive installation of planted vegetation resistant to the bending caused by the winds.
Carried out at Cape Verde.
Investigators: unknown.
Appendix VI b. p. 2

Dlii + Jlii
Improvement of efficiency of solar drying potato mixes in both: dry highlands and more humid lowlands.
Carried out in Peru with Italian funding.
Investigators: International Potato Centre (IPC), Lima, Peru (including local people).

Dlii + Jlii
Evaluation of solar driers for crops.
Carried out in Fiji.
Investigators: Same Research Division as mentioned above (A1).

G1 + I + L2i + O1
a) Wind erosion research and related characteristics and aerodynamic and microclimatic effects of windbreaks in the arid zone and
b) Detailed analysis of windbreak effects and regional land management on agricultural production.
Carried out in Tunisia, financed by International Development Research Centre (IDRC), Ottawa, Canada.
Investigators: INRAT (Tunis) and Station de Bioclimatologie (INRA, Montfavet) in the North and the Centre of Tunisia (Mme J. Bonzarti); Institut de Recherche des Zones Arides, Medenine and Station de Bioclimatologie (INRA, Montfavet France) in the arid South of Tunisia (Dr. G. Guyot).

G1 + L2i + O1
Study of the effects of PAULOWNIA-trees in association with crops on climate, wind erosion and agricultural production in the plains of Central-East China (lower basin of the Yellow River).
Carried out in China, financed by IDRC.
Investigators: Station de Bioclimatologie (INRA, Montfavet, France) (Dr. G. Guyot) and local people.

G1 + L2i + O1 + P1
Traditional wind breaks and their potential in irrigated areas, such as the Gezira Scheme, the Sudan (reduction of advective stress; reduction of damage from blown sand in wind erosion).
Carried out in the Sudan.
Investigators: Department of Environmental Sciences and Natural Resources, University of Gezira, Wad Medani, the Sudan (Dr. H.S. Adam, with collaboration of Hydraulics Research Station, Wad Medani and Gezira University Department of Agricultural Engineering) and T.T.M.I.-project, Department of Physics and Meteorology, Agricultural University, Wageningen, The Netherlands (Prof. C.J. Stigter).
CASE STUDIES - PLANNED AND ONGOING PROJECTS

A1
Intercropping of traditional and commercial crops under coconuts
Carried out in Fiji.
Investigators: Research Division, Department of Agriculture, Ministry of Primary Industries, P.O. Box 77, Nausori, Fiji.
Details to be obtained from the Annual Research Reports of that Research Division (Dr. P. Sivan, Assistant Director of Agriculture (Research)).

A1 + F1
Evaluation of alley farming techniques using leguminous trees (traditional agroforestry with livestock production).
Carried out in Nigeria.
Investigators: Humid zones programme of International Livestock Centre for Africa (ILCA), Ibadan, Nigeria.

A1 + C1 + I
A quantification of effects of the reintroduction of traditional light shading of trees on tea in Kenya.
Carried out in Kenya.
Investigators: Tea Research Foundation of Kenya (Dr. C.O. Othieno), (Dr. C. L. Coulson) Crop Science Department, University of Nairobi and T.T.M.I.-project, Department of Physics and Meteorology, Agricultural University, Wageningen, The Netherlands (Prof. C.J. Stigter).

A2 + A3 + F2
Implementation of mulching when introducing potato to warm climates (directed at extensionists).
Carried out in South East Asia, funded by the Australian Development Bank.
Investigators: Local with International Potato Centre (IPC) (Extension of an earlier research carried out in Peru, Philippines, Indonesia, Vietnam).

B1ii + G2
Storage of consumption (as opposed to seed) potatoes under warm environments, capitalizing on evaporative cooling and increased reflectivity of simple constructions.
Carried out in Peru.
Investigators: International Potato Centre (IPC), Lima, Peru (including local people).
Huxley, P.A. (Ed.), 1983
Plant research and agroforestry
ICRF, Nairobi, Kenya.

Jackson, I.J., 1977
Climate, water and agriculture in the tropics.

Jackson, J.E., 1983
Light climate and crop-tree mixtures.
In: P.A. Huxley (Ed.), Plant research and agroforestry.
ICRF, Nairobi, Kenya.

Kang, B.T., Wilson, G.F. and Lawson, T.L., 1984
Alley cropping: a stable alternative to shifting cultivation.
IITA, Ibadan, Nigeria.

Karing, P.H., 1979
Microclimatological maps of farming areas.
Gidrometeoizdat, Leningrad, USSR.

The prospects for small scale irrigation in sub-Saharan Africa.
Agric. 14: 115-122.

Kibardin, R.E., Olifer, E.P. and Shkreba, V.S., 1975
Plant protection from frosts using irrigation.
Gidrometeoizdat, Leningrad, USSR.

Kivi, K. (Comp.), 1980
Studies of microclimate of agricultural land in the Estonian SSR.
"Valgus", Tallin, USSR.

World systems of traditional resource management.
Winston & Sons and Edward Arnold, London, UK.
Kolovskov, P.I., 1971
The climatic factor in agriculture and agroclimatic zoning.  
Gidrometeoizdat, Leningrad, USSR.

Konstantinov, A.G. and Sturzer, L.R., 1974
Woods as windbreaks and the harvest.  
Gidrometeoizdat, Leningrad, USSR.

Konstantinov, L.K., 1985
The protection of orchards from sharp temperature fluctuations and frosts.  
Gidrometeoizdat, Leningrad, USSR.

Kurtener, D.A. and Chudnovsky, A.F., 1969
Calculation and regulation of the temperature regime in open and covered soil.  
Gidrometeoizdat, Leningrad, USSR.

Kurtener, D.A. and Chudnovsky, A.F., 1979
Agroclimatic bases of the improvement of soil temperature.  
Gidrometeoizdat, Leningrad, USSR.

Lal, R., 1984
Soil erosion from tropical arable lands and its control.  

Lyles, L., 1985
Predicting and controlling wind erosion.  

Midmore, D.J., 1983b
Factors influencing the development of the potato and its yield under hot conditions.  

Midmore, D.J., Accatino, P. and Berrios, D., 1983
Potato production under shade in hot climates.  
REFERENCES OF MAIN TEXT AND CASE STUDIES

(not mentioned in previous list)

Abe, I. and Takahashi, S., 1955
Studies on the microclimate and growth of soybeans interplanting in the potato fields.

Acland, J.D., 1971
East African crops.

Adams, J.E. and Arkin, G.F., 1977
A light interception method for measuring row crop ground cover.

Akobundu, I.O., 1982
Live mulch crop production in the tropics.
World Crops, July/August: 125-126 and 144-145.

Akroyd, D., 1985
Policy priorities for agricultural development in Africa with particular reference to agricultural project planning.

Altieri, M.A. and Farrell, J. 1984
Traditional farming systems of South-Central Chile, with special emphasis on agroforestry.
Agrofor. Syst. 2: 3-18.

Anonymous, 1982
Research and agricultural development in Nigeria.

Armbrust, D.V., 1979
Wind- and sandblast- damage to tobacco plants at various growth stages.

Armbrust, D.V., 1985
Windstorms carry away plant cells too.
Agric. Res. 33: 5-6.

Asai, T., 1951
The effects of windbreak for going up (of) the water temperature.
J. Agric. Meteorol. (Japan), 7(3, 4), no pages known.

Beets, W.C., 1978
The agricultural environment of Eastern and Southern Africa and its use.
Agric. Env. 4: 5-24.
Belshaw, D., 1980
The case of inter-cropping techniques in East Africa.
In: Brokensha et al. (Eds.).

Blaikie, P., 1985
The political economy of soil erosion in developing countries.

Brandner, F.C., 1982
Increase of irrigation efficiency by means of windbreaks.

Brandner, F.C., 1985
Mikroklimatische Bedingungen für die Agrarproduktion in Al Hassa;
b) Felduntersuchungen über die Produktionsbedingungen eines
Alfalfa-bestandes im Einflussbereich einer Palmwedelwindschutzhecke.
Leichtweiss-Institut für Wasserbau der technischen Universität
Braunschweig, Mitteilungen Heft 84: 27-302.

Indigenous knowledge systems and development.
University Press of America, Lanham, USA.

Planning technologies appropriate to farmers: concepts and procedures.
Economics Program, CIMMYT, Mexico.

Casada, J.H., Walton, L.R. and Wells, L.G., 1980a
Wind drag on Burley Tobacco plants.
Trans. ASAE 23: 189-191.

Casada, J.H., Walton, L.R., Swetnam, L.D. and Duncan, C.A., 1980b
Improving wind resistance of Burley Tobacco.
Bulletin 717, Univ. Kentucky Agric. Exp. Station, KE, USA.

Cionco, R.M., 1983
On the coupling of canopy flow to ambient flow for a variety of vegetation
types and densities.

Combe, J., 1982
Agroforestry techniques in tropical countries: potentials and limitations.

Compton, J.L., 1984 (2nd edition)
Linking scientist and farmer: rethinking extension’s role.
In: M. Drosdoff (Ed.), World Food Issues. Center for the analysis of
world food issues, PIA, Cornell University (IT, USA).

Daigo, Y. and Maruyama, E., 1952
Micro-meteorological study on the effect of straw-matting.
Daigo, Y. and Maruyama, E., 1954
On the straw fence as a wind-break in farm field.
J. Agric. Meteorol. (Japan) 10(1, 2), no pages known.

Denevan, W.M., 1980
Latin America
In: G.A. Klee (Ed.).

Indigenous Agroforestry in the Peruvian Amazon: Bora Indian management of swidden fallsows.
Interciencia 9(6): 346-357.

Dyson-Hudson, N., 1984
Adaptive resource use strategies of African pastoralists.

Egger, K., 1981
Ecofarming in the tropics – characteristics and potentialities.

Egger, K., 1983
Oekologischer Landbau in den Tropen.
Umschau 83, Heft 19: 569-573.

Leaf area, light transmission, roots and leaf damage in nine tropical plant communities.
Agro-Ecosyst. 7: 305-326.

The Chagga homegardens: a multistoried agroforestry cropping system on Mt. Kilimanjaro (Northern Tanzania).
Agrofor. Syst. 2: 73-86.

Flinn, J.C. and Lagemann, J., 1980
Evaluating technical innovations under low-resource farmer conditions.

Frère, M. and Popov, G.P., 1979
Agrometeorological crop monitoring and forecasting.
FAO Plant Production and Protection Paper 17, FAO, Rome, Italy

Fryrear, D.W. and Downess, J.D., 1975
Consider the plant in planning wind erosion control systems.
Trans. ASAE 18(6): 1070-1072 + 1075.

Bean growth and light interception in a bean-maize intercrop.
Field Crop Res. 4: 313-320.
Geertz, C., 1983
Local knowledge.
Basic Books Inc., New York, USA.

Gladwin, C.H., 1980
Cognitive strategies and adoption decisions: a case study of non-adoption of an agronomic recommendation.
In: Brokensha et al. (Eds.).

The ecological basis for the application of traditional agricultural technology in the management of tropical agro-ecosystem.
Agro-Ecosyst. 7: 173-185.

Gliessman, S.R., 1984
An agro-ecological approach for researching sustainable agro-ecosystems.

Golob, P., 1984
Improvements in maize storage for the smallholder farmer.
Trop. stored Prod. Inf. 50: 14-19.

Green, C.F. and Deuchar, C.N., 1985
On improved tube solarimeter construction.
J. Exp. Bot. 35: 690-693.

Greenland, D.J., 1975
Bringing the green revolution to the shifting cultivator.
Science 190: 841-844.

Greenwood, N.H., 1980
North America.
In: Klee (Ed.).

Gregory, J.M., 1984
Prediction of soil erosion by water and wind for various fractions of cover.
Trans. ASAE 27: 1345-1350 + 1354.

Hagen, L.J. and Skidmore, E.L., 1974
Reducing turbulent transfer to increase water-use efficiency.

Hall, J.A., 1982
The place of climatic hazards in food scarcity: a case study of Belize.
In: Hewitt (Ed.).

Hara, S., 1950
On experiment in the forms of seed-beds and ridge-farming.
Harrison, P., 1982
The new age of organic farming.
New Scientist, 13 May: 427-429.

Harwood, R.R., 1979
Small farm development: understanding and improving farming systems in
the humid tropics.
Westview Press, Boulder, CO, USA.

Hawskworth, D.L., (Ed.) 1984
Advancing agricultural production in Africa.

Holzberg, I.A., 1961
Agroclimatic characteristics of frosts in the USSR and methods of combat
against them.
Gidrometeoizdat, Leningrad, USSR.

Annual Reports
IITA, Ibadan, Nigeria.

ILEIA, 1984
Newsletter Information Centre for Low External Input Agriculture.
Nr. 1. ILEIA, Leusden, The Netherlands.

ILEIA, 1985
Newsletter Information Centre for Low External Input Agriculture.
Nrs. 2, 3 and 4. ILEIA, Leusden, The Netherlands.

Jackson, I.J., 1982
Traditional forecasting of tropical rainy seasons.

Jaffe, M.J., 1980
Morphogenetic responses of plants to mechanical stimuli or stress.
Bioscience 30: 229-243.

Janzen, D.H., 1975
Ecology of plants in the tropics.

Kawamata, M., Tsukijima, Y. and Sato, T. 1957
On the effects of shelter-hedge, alternately planted Miscanthus Senensis
Anders. var Condensatus Makino and Pennisetum Purpureum Schumach, for two
side of Uplandrice field against Typhoon.

Keatinge, J.D.H., Dennett, M.D. and Rodgers, J., 1985
The influence of precipitation regime on the management of three-course
crop rotations in northern Syria.
Klee, G.A., 1980
Traditional wisdom and the modern resource manager.
In: Klee (Ed.).

Lai, R. and Cummings, D.J., 1979
Clearing a tropical forest I. Effects on soil and micro-climate.
Field Crop Res. 2: 91-107.

Lal, R. and Greenland, D.J. (Eds.), 1979
Soil physical properties and crop production in the tropics.

Lang, A.R.G., 1978
Note on the cosine response of cylindrical net radiometers.

Lawton, H.W. and Wilke, P.J., 1979
Ancient agricultural systems in dry regions.
In: A.E. Hall et al. (Eds.), Agriculture in semi-arid environments.
Springer-Verlag, Berlin, Germany.

Lee, D.H.K., 1957
Climate and economic development in the tropics.
Greenwood Press, Westport (CON.), USA.

Litscher, T. and Whiteman, P.C., 1982
Light transmission and pasture composition under smallholder coconut plantations in Malaita, Solomon Islands.

Lomotono, B.S. and Baradas, M.W., 1983
Guidance material for agrometeorological services to rice farmers.
WMO-CAgM Report 19, Geneva, Switzerland.

Loomis, R.S., 1984
Traditional agriculture in America.

Lyles, L. and Allison, B.E., 1981
Equivalent wind-erosion protection from selected crop residues.
Trans. ASAE 24: 405-408.

Manintveld, K. and Soreé, H., 1982
Low-external-input agriculture in developing countries: a fact finding on organisations and persons.
ETC. Leusden. The Netherlands.

Mann, H.S., Lahiri, A.N. and Pareek, O.P., 1976
A study on the moisture availability and other conditions of unstabilised dunes in the context of present land use and the future prospects of diversification.
Maruyama, E. and Yamamoto, Y., 1953
On the role of the bamboo blades as a windbreak in farm field.

Matteson, P.C., Altieri, M.A. and Gagné, W.C., 1984
Modification of small farmer practices for better pest management.

McFarland, M.J., 1983
Agricultural Climatology: a review of the science and the potential.

McNaughton, K.C., 1983
The direct effect of shelter on evaporation rates: theory and an experimental test.

Meyer, L.D. and Moldenhauer, W.C., 1985
Soil erosion by water: the research experience.
Agric. Hist. 59: 192-204.

Midmore, D.J., 1983a
The use of mulch for potatoes in the hot tropics.

Midmore, D.J., 1984
Potato (Solanum spp.) in the hot tropics I. Soil temperature effects on emergence, plant development and yield.
Field Crop Res. 8: 255-271.

Midmore, D.J., 1985
Intercropping Potato (Solanum spp.) with maize in warm climates.
In: Proceed. VIIth ISTRC Confer., Guadeloupe.

Miller, D.H., 1981
Energy at the surface of the earth.

Miller, S.F., 1982
The effects of weed control technological change on rural communities.
Outl. Agric. 11: 172-178.

Miquel, S. and Hladek, A., 1984
Sur le concept d'agroforesterie: exemples d'expériences en cours dans la région de Makokou, Gabon.

Monteith, J.L., 1985
Weather and Agriculture.
Morales, H.L., 1984

Murton, B.J., 1980
South Asia.
In: Klee (Ed.).

Neal, S.B.H.C., 1975
The development of the thin-film naphthalene mass-transfer analogue technique for the direct measurement of heat-transfer coefficient. Int. J. Heat Mass Transfer 18: 559-567.

Obaga, S.O., 1984
Shade trees in tea - a review.

Okigbo, B.N. and Greenland, D.J., 1976
Intercropping systems in tropical Africa.
In: Papendick et al. (Eds.).

Oldeman, L.R., 1982
A study of the agroclimatology of the humid tropics of South-East Asia.
WMO-Tech. Note No. 179 (WMO-No. 597), Geneva, Switzerland.

Ramdas, L.A., 1951
Micro-climatological investigations in India.

Rhoades, R.E., 1984
Understanding small-scale farmers in developing countries: sociocultural perspectives on agronomic farm trials.

Richards, P., 1980
Community environmental knowledge in African rural development.
In: Brokensha et al. (eds.).

Robertson, G.W., 1980
The role of agrometeorology in agricultural development and investment projects.
WMO-Tech. Note No. 158 (WMO-No. 536), Geneva, Switzerland.

Röling, N., 1981
Promoting research utilization: some key-concepts and a case study from Kenya.
OECD Workshop on "Linkages between agricultural research and farmers", OECD, Paris.
Russel, E.W., 1973 (10th Ed.)
Soil conditions and plant growth.

Ruthenberg, H., 1976 (2nd Ed.)
Farming systems in the tropics.

Sharma, V.S. and Ranganathan, V., 1985
The world of tea today.

Smith, L.P. (ed.), 1972
The application of micrometeorology to agricultural problems.
WMO-Tech. Note No. 119 (WMO-No. 298), Geneva, Switzerland.

Stewart, J.I. and Hash, C.T., 1982
Impact of weather analysis on agricultural production and planning decisions for the semi-arid areas of Kenya.

Stigter, C.J., 1981
Potential of modern weather data technology for relevant agro-meteorology in developing countries.
In: A. Weiss (Ed.): Computer Techniques and Meteorological Data applied to Problems of Agriculture and Forestry: A Workshop.
National Science Foundation, Anaheim (CA), USA.

Stigter, C.J. and Uiso, C.B.S., 1981
Understanding the Piche evaporimeter as a simple integrating mass transfer meter.

Stigter, C.J., 1982b
The use of physics in agricultural research.

Stigter, C.J., 1984a
Forecasting and weather services for agriculture in Africa.
In: Hawksworth (Ed.).

Evaporation data from a Piche evaporimeter - A comment using Tanzanian results.
J. Hydrol. 73: 193-198.

Stigter, C.J., Mjungu, Y.B. and Waryoba, J.M., 1984d
An outdoor demonstration experiment on the effect of soil albedo on soil surface temperature.
Stigter, C.J., 1985b
In: C.J. Stigter (Ed.), Ninth Annual Report, Section Agricultural Physics, Physics Department, University of Dar es Salaam, Tanzania.

Stigter, C.J., 1985h
Working Group on Microclimate Management and Manipulation in Traditional Farming.
Report of the first session. WMO, CAgM. Geneva, Switzerland.

Stigter, C.J., 1986
Techniques improving the microclimate: traditional farmers know more about it. (In Dutch: Technieken die het microklimaat verbeteren: traditonele boer en weten er meer van).
Revolution, in press.

Sturrock, J.W., 1978
Effects of wind.
Science 200: 1263-1264.

Suzuki, S., Arai, T. and Hamasa, K., 1957
Strawberry cultivation on staircase-like slopes.
Mem. Ind. Meteorol. (Japan) 21(1), no pages known.

Tanaka, S., Sano, H., Tanizawa, T. and Kodera, S., 1954

Tanaka, S., Sano, H., Tanizawa, T. and Kakinuma, S., 1959
Studies on the control of wind erosion (7): Wind erosion prevention by catch ditch of flying soil.

Thurston, H.D. and Glass, E.H., 1984 (2nd Ed.)
Plant protection in developing countries: alternative strategies.
In: M. Drosdoff (Ed.), World Food Issues, Center for the analysis of world food issues, PIA, Cornell University (IT, USA).

Uemara, K., Mihara, Y., Hanyu, J. and Omoto, Y., 1974
Meteorological Hazards.
In: Mihara (Ed.).

Ujah, J.E. and Adeoye, K.B., 1984
Effects of shelterbelts in the Sudan Savanna zone of Nigeria on microclimate and yield of millet.

Voeykov, A.I., 1963
Man's impact on nature.
Acad. of Science Publ. House., Moscow, USSR.
Waddell, E., 1983
Coping with frosts, governments and disaster experts: some reflections based on a New Guinea experience and a perusal of the relevant literature.
In: Hewitt (Ed.).

Wakua, T.A.T. and Miller, D.A., 1978
Leaf water potentials and light transmission in intercropped sorghum and soybeans.

Whiteman, P.T.S., 1985
The mountain environment: an agronomist's perspective with a case study from Jumla, Nepal.
Mt. Res. Dev. 5: 151-162.

Whitney, J., 1980
East Asia.
In: Klee (Ed.).

Whyte, W.P., 1981
Participatory approaches to agricultural research and development. A state of the art paper. Special Series on Agricultural Research and Extension.
Rural Development Committee, Centre for International Studies, Cornell University (Ith, USA).

Wilken, G.C., 1975
Aspects of resource management by traditional farmers. Ch. III in:
H.H. Biggs and R.L. Tinnermeier (Eds.), Small farm agricultural development problems.
Colorado State University, Fort Collins (Co., USA).

W.M.O., 1981
Guide to Agricultural Meteorological Practices.
WMO, No. 134, Geneva, Switzerland.

W.M.O., 1984
Working Group on the transfer of knowledge and techniques in operational agrometeorology (plants and animals). Report of the first session.
WMO, CAgM, Geneva, Switzerland.

Yao, A.Y.M., 1981
Agricultural climatology.

Yoshino, M.M. (Ed.), 1984
Climate and agricultural land use in Monsoon Asia.
University of Tokyo Press, Tokyo, Japan.
Microclimate Management and Manipulation in Traditional Farming

Address to which the tear-out sheets should be sent:

Prof. C.J. Stigter
Agricultural University
Department of Physics and Meteorology
Duivendaal 1
6701 AP Wageningen
The Netherlands

The notes on Appendix VI urge the need for collection of further examples of the kind given in that Appendix. The reader is requested to kindly complete the form given below and mail it to the above address.

I Examples of Case Studies

II Examples of planning and on-going project case studies

III Examples of references for a selectively annotated bibliography

IV Name and address of author(s) or institute(s) pertinent to the examples

V Name and address of sender.
TEAR-OUT SHEETS

Microclimate Management and Manipulation in Traditional Farming

Address to which the tear-out sheets should be sent:

Prof. C.J. Stigter
Agricultural University
Department of Physics and Meteorology
Duivendaal 1
6701 AP Wageningen
The Netherlands

The notes on Appendix VI urge the need for collection of further examples of the kind given in that Appendix. The reader is requested to kindly complete the form given below and mail it to the above address.

I Examples of Case Studies

II Examples of planning and on-going project case studies

III Examples of references for a selectivley anotated bibliography

IV Name and address of author(s) or institute(s) pertinent to the examples

V Name and address of sender.
Microclimate Management and Manipulation in Traditional Farming

Address to which the tear-out sheets should be sent:

Prof. C.J. Stigter
Agricultural University
Department of Physics and Meteorology
Duivendaal 1
6701 AP Wageningen
The Netherlands

The notes on Appendix VI urge the need for collection of further examples of the kind given in that Appendix. The reader is requested to kindly complete the form given below and mail it to the above address.

I Examples of Case Studies

II Examples of planning and on-going project case studies

III Examples of references for a selectively annotated bibliography

IV Name and address of author(s) or institute(s) pertinent to the examples

V Name and address of sender.
Microclimate Management and Manipulation in Traditional Farming

Address to which the tear-out sheets should be sent:

Prof. C.J. Stigter
Agricultural University
Department of Physics and Meteorology
Duivendaal 1
6701 AP Wageningen
The Netherlands

The notes on Appendix VI urge the need for collection of further examples of the kind given in that Appendix. The reader is requested to kindly complete the form given below and mail it to the above address.

I Examples of Case Studies

II Examples of planning and on-going project case studies

III Examples of references for a selectively annotated bibliography

IV Name and address of author(s) or institute(s) pertinent to the examples

V Name and address of sender.
Microclimate Management and Manipulation in Traditional Farming

Address to which the tear-out sheets should be sent:

Prof. C.J. Stigter
Agricultural University
Department of Physics and Meteorology
Duivendaal 1
6701 AP Wageningen
The Netherlands

The notes on Appendix VI urge the need for collection of further examples of the kind given in that Appendix. The reader is requested to kindly complete the form given below and mail it to the above address.

I Examples of Case Studies

II Examples of planning and on-going project case studies

III Examples of references for a selectively annotated bibliography

IV Name and address of author(s) or institute(s) pertinent to the examples

V Name and address of sender.