WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR AGRICULTURAL METEOROLOGY

CAgM Report No. 93

EXPERTS FOR COLLECTION OF CASE STUDIES OF ECONOMICALLY BENEFICIAL AGROMETEOROLOGICAL APPLICATIONS AND SERVICES AND OTHER SUCCESS STORIES IN AGROMETEOROLOGY FOR POLICY MATTERS

Final Report of the CAgM Expert Team

Submitted by by
Dr. Wolfgang Baier (Coordinator)

WMO/TD No. 1202
Geneva, Switzerland
March 2004
CONTENTS

INTRODUCTION .......................................................................................................................... 1

ANALYSIS OF SUBMISSIONS .................................................................................................... 2

SUMMARIES OF CASE STUDIES SUBMISSIONS ................................................................. 3

1. Farmweather - a Case Study in Agrometeorology .......................................................... 3
2. Report on a case study of economically beneficial agrometeorological applications for cowpea cultivation ................................................................. 3
3. A few examples of agrometeorological services for cereal production in Kazakhstan .................................................................................................................. 3
4. Ecuador - a case study in Agrometeorology ................................................................... 4
5. ISOP - An integrated system to real-time assessment of forage production variability over France ........................................................................................................... 4
6. Combating desertification and reintroducing agricultural production by appropriate planting and multiple shelterbelts in Sahelian conditions and some simple agronomic measures .......................................................................................................................... 5
7. Use and suitable designs of shelterbelts and scattered trees as well as grasses for protecting agricultural production and infrastructure from wind driven sand encroachment and expanding desertification .................................................................................................................. 5
8. Improved underground grain storage microclimate in cracking clay extended safe storage time by designing shallow pits, using chaff linings and constructing wide surface caps .......................................................................................................................... 6
9. Testing alley cropping (contour hedgerows) in semi-arid areas on flat and sloping land: soil and water conservation, competition, yields and economic factors ........................................................................................................... 6
10. Water waste in traditional and more recently developed on-farm irrigation management in the Gezira Scheme in Central Sudan .................................................................................................................. 7
11. The U. S. Drought Monitor .............................................................................................. 7
12. The weekly weather and crop bulletin serving U. S. Agriculture .................................. 8

OTHER SUBMISSIONS ................................................................................................................. 8

1. Drought and desertification in Uzbekistan ....................................................................... 8
2. Agrometeorological products and their economic benefits in the Russian Federation .................................................................................................................. 8
3. Mapping ink disease hazard for oaks in France ............................................................... 8

OTHER SOURCES OF ‘CASE STUDIES’ .................................................................................... 8

ADVISORY WORKING GROUP RECOMMENDATIONS ................................................................ 13

CONCLUSIONS ............................................................................................................................ 14

APPENDIX .................................................................................................................................. 20

Annexes (1 to 15)
INTRODUCTION

The Commission for Agricultural Meteorology reviewed at CAgM-XII (Accra, February 1999) the report entitled “WMO/CAgM Related Achievements in Agricultural Meteorology.” The report summarized submissions from 16 Member countries and stressed the importance of reflecting fully the real impact of the work of the Commission at the global level. Subsequently, the report was published as CAgM Report No. 83 (WMO/TD No. 1033, October 2000).

As a follow-up to the above compilation of achievements, the Commission established an Expert Group for the Collection of Case Studies of Economically Beneficial Agrometeorological Applications and Services and on other Success Stories in Agrometeorology for Policy Matters (Para. 8.1.3 of the Abridged Final Report of CAgM-XII, WMO-No. 900).

Because the approval process for implementing the decisions of the session was delayed by seven months, the work of the expert group for collection of case studies in agrometeorology - like that of another expert group, working groups and rapporteurs - commenced almost a year after CAgM-XII. In the memo of 12 November 1999 from the WMO Secretariat, 13 experts were appointed to contribute to the work of the expert group (for details see Appendix I):

- Mr. Vladimir S. Antonenko, Ukraine; Mr. Manuel Carvajal Ortiz, Ecuador; Dr. Lubov Lebed, Kazakhstan; Mr. Gay Munthali, Malawi; Ms Binh Nguyen Thi Thu, Viet Nam; Mrs. Victorine Pérarnaud, France; Dr. Shuanghe Shen, China; Mr. Denis Tohio, Benin; Dr. Vladimir Usmanov, Uzbekistan; Ms Olga Ustinova, Russian Federation; Dr. Petrit Zorba, Albania; Mr. Richard N. Whitaker, Australia; with Dr. Wolfgang Baier, Canada, as Co-ordinator.

The President of CAgM in his Circular Letter No. 2 dated 26 July 2000 encouraged all CAgM members to provide examples of such case studies not only from their country but also from their Regional Association. In Response to the President’s call letter, Dr. R. P. Samui, India, requested and received information on the format of the submissions, since he would like to submit some case studies from RA-II (Asia) Region.

By the end of the year 2000, proposals for such case studies were submitted from Australia, Benin, Ecuador, France, Russian Federation and Uzbekistan, whereas other experts had indicated their intention to submit proposals.

To assist the experts of the group in preparing their final submissions, the case study: Farmweather - a Case Study in Agrometeorology, submitted by Richard, N. Whitaker (Australia), was further developed into a model submission and attached to the first progress report issued in January 2001.

The CAgM Advisory Working Group at its meeting in Florence, 2 to 5 April 2001 reviewed the progress made so far with the collection of case studies and recommended the inclusion of existing contributions, as well as additional case studies from a variety of sources in the final report. There were no specific decisions regarding the selection of case studies but a standard format was recommended for their presentation in the final report, as follows:
Members of the Advisory Working Group also offered their assistance in providing case studies or contacting potential contributors. This resulted in the submission of case studies from: Dr. Donald A. Wilhite (USA); Thomas L. Puterbaugh (USA) jointly with Bradley R. Rippey (USA); and five case studies from Prof. C.G. Stigter (The Netherlands).

Appendix 1 gives the name, affiliation and address of all nominated expert group members and other contributors. It also indicates whether or not a report was received and where it is included in this Final Report (i.e. in Table 1 and in the Annexes).

ANALYSIS OF SUBMISSIONS

Table 1 shows a summary of the Case Studies submissions.

The short title describes the nature of the case study. Column 2 lists the name of the Resource Person(s), country of origin, and associated WMO Regional Association.

The Comments give some background on the case study with respect to the source of the information and its status in this final report.

The Column “Related to new “CAgM OPAG” relates each case study to the proposed Open Programme Area Groups (OPAG) which will be discussed at CAgM-XIII and which were outlined in Circular Letter No. 4 of the President of CAgM.

Within the table, the submissions are in the order as follows:

A. Original “Farmweather” report which was developed at the early stage of the work to assist the experts in preparing their submissions.
1. Fully documented case studies submitted by expert group members in order of WMO Regional Associations (RA).
2. Fully documented case studies received in response to initiatives taken by CAgM Advisory Working Group members at their meetings in April 2001.
3. Contributions received but not edited and not in a format suitable for case studies. This section is for information only.

The Case Studies submissions are presented in Annexes 1 to 15.
SUMMARIES OF CASE STUDIES SUBMISSIONS

This section presents summaries of the fully documented 12 case studies submissions for which an abstract was available (Table 1-A, B and C).

1. Farmweather - a Case Study in Agrometeorology (Table 1- A1, Annex 1)
   (Submitted by R. N. Whitaker, Australia, RA V)

Abstract

In 1991, meteorological staff from the Australian Bureau of Meteorology toured the cotton growing areas of northern New South Wales, conducting interviews with cotton farmers and other farmers from surrounding areas. The combination of the expertise of the meteorologist and farmer resulted in the formation of the “Farmweather” service which now provides weather forecast and agronomic advice to a large part of agricultural Australia. In 1996 and 1997, surveys were issued to a wide area of rural Australia to determine the impact of the “Farmweather” service and revealed that the economic benefits based on only the production of four main export crops (wheat, cotton, barley and sorghum) were about six times the cost of producing the services.

2. Report on a case study of economically beneficial agrometeorological applications for cowpea cultivation (Table 1- B2, Annex 2)
   (Submitted by Dénis Tohio, Bénin, RA I)

Abstract

Cowpea is a very important subsistence crop and is part of several foodstuffs found in Africa south of the Sahara. It is a leguminous plant with seeds that are very rich in protein. Like most crops, cowpea is subject to climatic hazards and plays an important role in low-lying soil cropping systems in the dry savannah and Sahelian regions, where most crops fail. Unfortunately, cowpea is highly susceptible to insects, diseases and parasitic weeds, and is consequently very difficult to grow without using pesticides. Technical advice given to producers has led to a substantial improvement in cowpea production, but this increase is only possible when the plant’s requirements are taken into consideration. When agrometeorological applications are properly followed, they are often beneficial. However, in most cases, they are not used by most of the farming community, and are taking a long time to be popularized. They are often used primarily at sites where experiments have taken place.

3. A few examples of agrometeorological services for cereal production in Kazakhstan (Table 1- B 3, Annex 3)
   (Submitted by Lyubov Lebed, Kazakhstan, RA II)

Abstract

Cereal production is, along with livestock breeding, one of the main agricultural activities in Kazakhstan, which has an arid climate. According to statistical records, in the past 20 years the area planted with cereals has varied from 12 to 22 million hectares. Of this, 65 per cent is devoted to spring wheat, which is planted predominantly in the northern part of the country. The
agroclimatic conditions for spring wheat vegetation in northern Kazakhstan generally include a sufficient amount of warmth (with between 2,000 and 3,000 degree days over 10°C) and a lack of moisture (annual precipitation ranges from 250 mm to 350 mm). When favourable agrometeorological conditions exist in the northern part of Kazakhstan, high-tech farming in chernozemic soils can produce spring wheat yields of up to 3.0 tonnes per hectare without the use of irrigation. However, if we take into consideration all types of farms, average yield in the oblasts is considerably lower, ranging from 0.2 to 1.3 tonnes per hectare. In the past decade there has been a decline in spring wheat yields and in total cereal yields in Kazakhstan. In order to support grain production, the national Hydrometeorological Service is now upgrading its agrometeorological information services.

4. Ecuador - a case study in Agrometeorology  (Table 1- B 4, Annex 4)  
  (Submitted by Manual Carvajal, Ecuador, RA III)

Abstract

The name of Ecuador is due to its geographical location over the equatorial line, it shows a minimal climatic variation during the year. We are using some applications of the agrometeorological data, the principal is related to sowing and harvesting calendar that has an historical and practical application in agriculture meteorology. however forecast and frost control have a minimal application. Since five years ago the farmers are using agrometeorological data especially about solar radiation and specifically about sunshine, they have obtained some advances to improve the yields. Reduction of forest fires has been a new application, but it needs to be improved. The agrometeorological bulletins (monthly and decade [10 days]), is a tool for authorities and farmers, but it is necessary to redesign in order to obtain better results.

5. ISOP - An integrated system to real-time assessment of forage production variability over France (Table 1- B 5, Annex 5)  
  (Submitted by Ms. Victorine Pérarnaud, France, RA VI)

Abstract

Since 1997, an integrated system called ISOP has been developed between three French participants: the ministry of Agriculture (through its Department of Statistics, SCEES), the institute for Agronomical Research (INRA) and the national meteorological service (METEO-FRANCE). The purpose is to produce reliable estimations of the forage production, in order to give objective information to the ministry of Agriculture to estimate real production losses in case of local or global drought. Input data are various and multiple, including special daily meteorological parameters, percentages of soil types, nitrogen status and amounts and frequency of mowing or grazing, estimated from a national survey. The STICS crop model is applied to three kinds of grassland: permanent, temporary and pure legumes. The results are available for 200 regions of forage production (RFP) and synthesised in alert maps and temporal graphs for selected drought-stricken areas. This project started in 1997 [1] and a model was carried out in 1998 on 7 selected forage regions in the south-west of France to verify the feasibility and the accuracy of the ISOP system.
6. Combating desertification and reintroducing agricultural production by appropriate planting and multiple shelterbelts in Sahelian conditions and some simple agronomic measures (Table 1- C 6, Annex 6) *(Submitted by C. J. Stigter, The Netherlands, L. O. Z. Onyewotu and J. J. Owonubi, Nigeria, RA I)*

Abstract

Without participation of farmers, extension personnel and local scientists and without establishing a pilot project, the Nigerian government established large areas of multiple shelterbelts of *Eucalyptus camaldulensis* that controlled desertification well. Agrometeorological research showed that this unprepared introduction led to an inefficient system of belts. The research showed that different belt direction, much shorter distances between belts, less depth of the belts, pruning of tree roots and branches at the tree/crop interfaces, a scientific determination of planting dates, improved use of manure and participative management of belts and crops would have improved the system and its yields. Such measures, combined with the alternative choice for dense agroforestry parkland or for a combination of belts and scattered trees would have made the systems acceptable to farmers if they had been involved in the details of such choices.

7. Use and suitable designs of shelterbelts and scattered trees as well as grasses for protecting agricultural production and infrastructure from wind driven sand encroachment and expanding desertification. (Table 1- C 7, Annex 7) *(Submitted by C. J. Stigter, Ahmed Eltayeb Mohammed and Nawal K. Nasr Al amin, Sudan, RA I)*

Abstract

In Sudan, problems of wind induced sand encroachment towards an irrigated area could for the time being be solved by a planted *Eucalyptus microtheca* shelterbelt. Also sand settlement in the source area by trees and grasses to combat expanding desertification was successfully researched. Both studies quantified interaction of wind with trees and sand settlement to prevent this way further sand encroachment towards areas in use for agricultural production. The oldest work was on the use and on improved designs of shelterbelts to catch sand within and in front of the belt vegetation. A recommended improved design is now widely used to protect endangered parts of the Gezira irrigation scheme. The later work that was terminated only recently, dealt with the selection, establishment and suitability of trees and grasses for use in settling sand. This was done in the secondary source area of the moving sand originally studied near the endangered parts of the irrigation scheme. Recommendations on suitable species have been made.
8. Improved underground grain storage microclimate in cracking clay extended safe storage time by designing shallow pits, using chaff linings and constructing wide surface caps (Table 1-C 8, Annex 8)

(Submitted by C J. Stigter and Ahmed el-Tayb Abdalla, Sudan, RA I)

Abstract

Diminished food security due to increasing climate variability encouraged farmers in Central Sudan to experiment with possible improvements of their traditional underground storage pits for sorghum grain. Microclimate measurements of grain moisture contents, grain temperatures and pit air carbon dioxide contents in experimental pits made it possible to test and improve their designs. Farmer innovations of using pits of only 50 cm deep and applying chaff linings at bottom and sides of these shallow pits made safe storage possible during at least two consecutive bad rainy seasons. Wide above surface caps were a necessary condition added by the research experience.

9. Testing alley cropping (contour hedgerows) in semi-arid areas on flat and sloping land: soil and water conservation, competition, yields and economic factors (Table 1-C 9, Annex 9)

(Submitted by C J. Stigter, D.N. Mungai, C. K. Ong, J. M. Kinama and S.B.B. Oteng’i, Kenya, RA I)

Abstract

Alley cropping tested by Mungai et al. on flat land, with prunings incorporated into the soil and one in every four rows of maize replaced by trees in the agroforestry plots, showed already in the late eighties/early nineties that alley cropping was unsuitable for flat semi-arid areas, because of its high risks for the farmers. This was mainly due to poor crop yields caused by (i) low biomass production of the trees under the low rainfall conditions in semi-arid areas, not sufficiently improving soil fertility and other soil conditions, (ii) higher than foreseen competition between trees and crops for water and nutrients, because of more overlap of root zones than expected, also away from the trees and also at lower horizons. The work of Kinama et al. in the nineties proved that on sloping land (in our case ca. 15%), contour hedge rows and mulch on the surface, for a comparable tree system added to maize or cowpea crops, considerably reduced soil loss and to a lesser extent water runoff. It, however, also reduced crop yields considerably, for the same reasons as in alley cropping on flat land. Nevertheless, strong trade-offs between the erosion control and crop productivity need not be a major deterrent to adoption by farmers, provided the trees have direct and significant benefits to farmers such as producing fodder or tree products that can be well marketed.
10. **Water waste in traditional and more recently developed on-farm irrigation management in the Gezira Scheme in Central Sudan** (Table 1-C10, Annex 10)  
*(Submitted by C J. Stigter, Ahmed A. Ibrahim and Hussein S. Adam, Sudan, RA I)*

**Abstract**

In the Gezira irrigation scheme in Central Sudan, serious symptoms of water waste have been identified in the last two decades, especially in sorghum and groundnut fields. To quantify losses, water use efficiencies and related parameters were obtained for these two food crops under the traditional attended daytime water application and the newly evolved unattended continuous watering method. The study has revealed wastage of irrigation water in both irrigation methods but at different rates and also differently for each crop. Higher wastes were observed in the groundnut sub-fields, which crop also suffers from excess water, and for the drier of the two years as well as in the unattended fields. A first approximation could be given, still including readily available water at harvest, of minimum water requirements in attended watering for maximum yields. In the drier year, when more irrigation water was applied, an amount equal to 30 to 50% of these minimum water requirements was lost in evaporation from standing water/wet surface, which is the main unproductive water. More frequent land levelling, aiming at minimum standing water in better attended irrigation and at better farm management (e.g. weeding) are priority measures proposed.

11. **The U. S. Drought Monitor** (Table 1-C 11, Annex 11)  
*(Submitted by Donald A. Wilhite and Mark D. Svoboda, USA, RA IV)*

**Abstract**

The development of an effective drought monitoring system presents some unique challenges because of the slow onset nature of this natural hazard. Drought impacts are largely non-structural and regional in scale, making both assessment and response difficult. The different types of drought further complicate monitoring and impact assessment efforts. In 1999, an experimental drought assessment product, the U.S. Drought Monitor, was developed in the United States through a partnership between the National Drought Mitigation Center at the University of Nebraska, the U.S. Department of Agriculture, and the National Oceanic and Atmospheric Administration. Because of severe and widespread drought conditions in the United States at the time, this product became operational within a few months. The U.S. Drought Monitor is a weekly map that represents a snapshot of drought conditions. Authors of the product incorporate multiple climate indices and indicators in determining drought severity classes. A network of climatologists, hydrologists, and others at the state and regional scale are provided the opportunity to comment on drafts of the map before it is released to the public at the same time each week via the Internet. A scheduled map release time best meets the needs of the diverse user audience. In the past three years this product has become widely accepted by the scientific and policy communities, the private sector, and the media. More than 1.2 million hits on this map were recorded during 2001. In addition to users that directly access the web site, the map also appears in many local, regional, and national newspapers and on many television stations.
12. The weekly weather and crop bulletin serving U. S. Agriculture
(Table 1-C 12, Annex 12)
(Submitted by Thomas L. Puterbaugh and Bradley R. Rippey, USA, RA IV)

Abstract

The Weekly Weather and Crop Bulletin (WWCB) provides an invaluable source of information pertinent to regional, national, and international agriculture. Since 1978, the WWCB has been produced by the Joint Agricultural Weather Facility (JAWF), a global agricultural weather and information center located within the United States Department of Agriculture (USDA) in Washington, D.C. The JAWF is jointly operated by the Department of Commerce’s Climate Prediction Center (DOC/CPC), and USDA’s World Agricultural Outlook Board (WAOB) and the National Agricultural Statistics Service (NASS). The publication is a shining example of how two major departments within the federal government can mutually cooperate, combining meteorology and agriculture to provide a service that benefits the economic well-being of the nation. The WWCB highlights weekly meteorological and agricultural developments on a national and international scale. Written summaries of weather and climate conditions affecting agriculture are provided, along with detailed charts and tables of agrometeorological information that are appropriate for the season.

OTHER SUBMISSIONS

Three other submissions were received but they lacked the necessary formatting and other information essential for documenting a case study:

1. Drought and desertification in Uzbekistan (Table 1- D13, Annex 13) submitted by Dr. Vladimir Usmanov, Uzbekistan;

2. Agrometeorological products and their economic benefits in the Russian Federation (Table 1-D 14, Annex 14) submitted by Ms. Olga Ustinova, Russian Federation;

3. Mapping ink disease hazard for oaks in France (Table 1-D 15, Annex 15) submitted by Ms. Victorine Pérarnaud, France.

These three submissions contained interesting information but because of language difficulties and no abstract could be obtained they are included as submitted in Annexes 13 to 15.

OTHER SOURCES OF ‘CASE STUDIES’

There are of course numerous other sources where ‘case studies’, as defined in this report, are documented, such as handbooks on agrometeorology, journal publications, CAgM Circular Letters, CAgM reports and WMO Technical Notes. Most of these success stories are in the area of operational agrometeorology. The WMO Secretariat usually presents at CAgM
Sessions a document that lists publications brought out during the intersessional period, including proceedings, technical notes, brochures, and CAgM Reports (e.g. CAgM-XII/INF. 2 at CAgM-XII).

At the CAgM-XII Advisory Working Group meeting (Florence, April 2001), the Coordinator proposed in his progress report (Document 17, Agenda Item 14) other possible sources of case studies for future detailed documentation. From this report, the following examples were selected.

1. **Final reports of CAgM-XII Working Groups**

   Reports of CAgM-XII working groups and Rapporteurs will contain examples of case studies of economically beneficial agrometeorological applications with respect to the particular terms of reference for this group or rapporteurship. For instance, the chairperson (Ms V. Péranauad, France) of the Working Group on the Communication of Agrometeorological Information (Res. 10, CAgM-XII) already provided to the Coordinator information on three case studies from members of that group (Germany, UK and the Netherlands). Likewise, the Canadian member (Andrew Bootsma) of that working group compiled 12 examples of case studies in agrometeorology from WMO Regional Association IV.

2. **CAgM Report No. 83 (WMO/TD No. 1033, October 2000)**

   CAgM Report No. 83 lists 77 submissions from 16 countries received by the end of July 1998. From these submissions, seven examples were selected and presented in some detail. They are reproduced here to show what type of “case studies” are already available elsewhere:

   **Example 1:**
   Title: Natural Disaster in Agriculture – Israel
   Authors: Gat, Z., Rubin, S. and Horovitz, T.
   Originator: Mrs. Zipora Gat, Deputy Director, Applied Meteorology, Israel Meteorological Service, P. O. Box 25, Bet Dagan 50250, Israel.
   Reference: The document (12 Pages) submitted by the originator describes the contribution of agrometeorology to the identification and mapping of areas of natural disaster in agriculture in Israel. A 2-page summary was prepared from this document by W. Baier and presented in Example 1, CAgM Report No. 83

   **Example 2:**
   Title: Holding Back the Desert - A Eucalyptus Shelterbelt in Central Sudan.
   Authors: Mohammed, A. E., Stigter, C. J. and Adam, H. S.
Highlights: In Sudan, the land degradation caused by sand contributes to decertification. The paper describes the experience gained about sand deposition, tree species and design of eucalyptus shelterbelts established a decade ago at the northwest borders of the Gezira irrigation scheme in central Sudan.

Example 3:
Title: CAgM Related Achievements in Agricultural Meteorology - Botswana's experience
Originator: D. D. Dambe, Botswana Meteorological Service, P. O. Box 10100, Gaborone, Botswana
Reference: Example 3, CAgM Report No. 83.
Highlights: The Note summarizes agrometeorological services provided to farmers and Government resulting in improved farm management and policy decisions. Since the middle of 1980s, agrometeorological information has been one of the leading indicators of drought in Botswana. Agrometeorological information, such as the best time to plant, end of planting, types of crops to plant etc. based on results from various agrometeorological analysis, is normally provided to farmers through the media and agricultural extension. Agrometeorological advice is also utilized at policy and planning levels.

Example 4:
Title: Four Russian examples of agrometeorological achievements
Originator: Prof. I. G. Gringof, Senior Scientific Officer ARRIAM, Lenin Street 82, 249020 Obninsk, Kaluga Region, Russian Federation.
Reference: Specially prepared "Attachment" (2 pages). Example 4, CAgM Report No. 83.
Highlights: Russian example 1 - Agrometeorological justification of crop production in Russia
Russian example 2 - The handbook of agronomists on agricultural meteorology.
Russian example 3 - Weather and forage crops
Russian example 4 - Drought and winter cereal crops in Russia

Example 5:
Title: 5-day weather forecast by Telefax for agriculture in Switzerland
Highlights: The Swiss Meteorological Institute developed in 1994 a forecast for a 5-day period especially for agricultural establishments, its upstream and downstream enterprises, as well as for further outdoor activities. The forecast is produced daily since 1 March 1995. Clients can call it in by telefax whenever they wish to do so, against a corresponding charge. The 5-day forecast for agriculture contains a forecasting part in form of a text and 'particularities', such as recommendations (e.g. weather for hay harvest), warnings (e.g. frost warnings), and climate values (e.g. information on decades, months or seasons). Some of the agricultural works, which can be better planned and done due to the forecast are listed (e.g. sowing bed preparation, frost protection measures, irrigation management, optimization of plant protection measures, optimization of stock transport facilities, or optimization of crops (date or period), purchases, sales, quantities and qualities).

Example 6:

Title: Agrometeorology of multiple cropping in warm climates


Reference: Agrometeorology of multiple cropping in warm climates (1997) by C. Baldy and C. J. Stigter, INRA, Paris, 237 pp. Copy of this handbook has been deposited with the WMO Secretariat, World Climate Programme Department, Agricultural Meteorology Division. Example 6, CAgM Report No. 83.

Highlights: The book highlights the importance and the effects of microclimate modifications when different species are grown together in the same area. It demonstrates the significance of these practices and the positive character of certain combinations vis-à-vis yields, weed competition, attacks by parasites etc. It is necessary that the combinations be carefully selected to preclude adverse affects on the environment. This work has been conceived both as an instruction manual as well as a textbook reference for data (often very difficult to obtain) on the interactions of climate and modifications of cultivated plants whose growth requirements are different.

Example 7:

Title: Twelve examples of agrometeorological achievements in China
Highlights:

Chinese example 1 - Rural meteorological services net in Heilongjiang Province
Chinese example 2 - Application of remote sensing for crop monitoring
Chinese example 3 - Breeding hybrid seeds based on meteorological information
Chinese example 4 - Developing climatic resources by expanding ratoon rice
Chinese example 5 - Adjusting growing period of double cropping of rice to avoid plant stress
Chinese example 6 - Optimization of irrigation to save water
Chinese example 7 - Conserving soil moisture to protect winter wheat from injury
Chinese example 8 - Rotation system and water use efficiency
Chinese example 9 - Relation between weather and sheep feeding
Chinese example 10 - Forecasting date of flowering of pear and other trees
Chinese example 11 - Avoiding fish death by using weather risk forecast
Chinese example 12 - Application of climatic resources for growing vegetables in mountainous areas

3. Circular letter CAgM No. 10

Circular letter CAgM No. 10 (January 1999) from the President of the Commission for Agricultural Meteorology contains three Case studies of agrometeorological applications in short-term meteorological forecasts for agriculture:

Case study 1

Meteo France’s Services for Agriculture (submitted by Mrs. Victorine Pérarnaud, France)
- Forecasting - Agroclimatology - Agroclimatic Mapping

Case study 2

Short term meteorological forecasts for agriculture: Examples from Israel (submitted by Mrs. Zipora Gat, Israel):
- Methods of detailed forecasts of frost and low temperatures
- Forest Fire Forecasts (FFF)
- Agrometeorological software used in crop protection - forecasting outbreak of fire blight.
Case study 3

Example of decision making on choosing dates of field management based on agrometeorological information with the application of short-term forecasts (submitted by Prof. A. D. Kleschenko, Russian Federation)

Principal agrotechnical procedures and operation types:
- Soil treatment after precursor for winter crop
- Winter crop seeding
- Spring nitrogen feeding of winter crops
- Weed control
- Summer feeding of winter crops
- Potato hilling
- Antiphytophthora treatment of potato
- Cereal crop and potato harvesting

ADVISORY WORKING GROUP RECOMMENDATIONS

The Advisory Working Group (AWG) endorsed the Progress Report and made several recommendations with respect to the compilation of case studies:

1. It was suggested that the focus of the report be on socio-economic benefits and the major conclusions be highlighted. Also, a simpler format for the case studies was proposed (Final AWG Report, Agenda Item 14.3).

2. CAgM Report No. 87, which is now being published, contains the contributions from members of CAgM on agrometeorological applications and suitable examples from this publication could be used for the case studies (Final Report, Agenda Item 14.4).

3. Examples of the bulletins of forecasted data published in Germany. Furthermore, in some Regions there are combined operational activities on agricultural forecasting e.g. Germany and Austria; Paraguay, Uruguay, Argentina and Brazil (Item 14.5).

4. It is very important to demonstrate clearly the socio-economic benefits of agrometeorological applications in a simple and easily understandable format. As the proposed report on case studies is likely to be quite voluminous, it would be important to prepare a short information brochure highlighting the socio-economic benefits of the successful case studies (Item 14.6).

5. It is important to present a balanced approach between the different subjects and the different Regions. A matrix table could be used to achieve such a balance between the different subjects like cereals, forages, livestock, fisheries, drought, biodiversity, land management and the different Regional Associations (Item 14.7).

6. Authors are invited to submit suitable photographs to illustrate the text to make the report more attractive (Item 14.10).
The response to these recommendations was as follows:

1. A simpler format for case studies submissions was recommended to members of the Expert Group in the Memo of 15 June 2001 and was employed in most cases.

2. Advisory Working Group members had agreed to submit additional case studies and to encourage their colleagues to do so. This in fact resulted in the submission of seven case studies which are identified in Table 1, Section C.

3. Several photographs in colour were submitted but these are now included in the report because of their file size. They are however available upon request from the Coordinator.

4. A matrix table showing a balanced approach by Regions and commodities could not be prepared because of lack of information. Most case studies came from activities related to operational agrometeorological services and impacts of research. This is because in these fields it is feasible to identify socio-economic benefits.

5. Instead a matrix table showing a balanced approach by Regions and proposed CAgM Open Programme Areas (OPAGs) was prepared (Table 2). Of the 15 proposals for case studies, 6 would fall under OPAG Services and 9 under OPAG Impacts. There were no submissions under OPAG Support Systems, probably because it is difficult to quantify economic benefits due to network observations, data and information management, and technical support needed to advance science.

CONCLUSIONS

1. The response to the call for case studies submissions (10 Memos) was not as successful as hoped for, but 12 fully documented case studies and 3 other contributions were received.

2. The 15 contributions are summarized according to short title, resource person(s), country, WMO Regional Association, and proposed Open Area Programme Groups (OPAG) which will be discussed at CAgM-XIII (Table 2).

3. The case study “Farmweather”, which was received in the early stage of the project, was further developed into a model submission and distributed to expert group members in January 2001.

4. The CAgM Advisory Working Group reviewed the first progress report (April 2001) and made several recommendations with respect to format, additional sources for case studies and compilation of the information.

5. The 12 fully documented case studies are attached in detail as Annexes (1 to 12) with Abstracts given in the text.
6. Other sources of case studies - such as CAgM Reports, Circular Letters of the President of CAgM, and Final reports of CAgM Working Groups - were explored with examples given in the text.

7. A matrix table showing the case studies by WMO Regional Associations and CAgM OPAGs was prepared (Table 2)

8. Some colour photographs to illustrate the text are available.

9. It is recommended that this final report eventually becomes a numbered CAgM Report.

10. The preparation of a WMO popular bulletin, based on the material in this report, is recommended.
## Table 1.
### Summary of Case Studies

<table>
<thead>
<tr>
<th>Item</th>
<th>Short title</th>
<th>Resource Person (s)</th>
<th>Comments</th>
<th>Related to new CAgM OPAG (^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>Original “Farmweather” report received in May 2000 and then developed into a model for submission of case studies</td>
<td></td>
<td>From “Cottonfields” (1992) to “Farmweather” including 1996 economic evaluation</td>
<td>Services (Operational) (Farmers’ advisories)</td>
</tr>
<tr>
<td>1</td>
<td>Farmweather - a case study in agrometeorology</td>
<td>R. N. Whitaker Australia, RA V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B.</td>
<td>Fully documented Case Studies submitted by Expert Group members in order of WMO Regional Associations (RA)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Economically beneficial agromet applications for cowpea cultivation</td>
<td>Dénis Tohio Bénin, RA I</td>
<td>Report in French - translated into English by WMO Secretariat</td>
<td>Services (Operational) Farmers’ advisories</td>
</tr>
<tr>
<td>3</td>
<td>A few examples of agrometeorological services for cereal production in Kazakhstan</td>
<td>Lyubov Lebed Kazakhstan, RA II</td>
<td>Report in Russian - translated into English by WMO Secretariat. Agromet forecasts of cereal harvest yields important to assess real incomes in production</td>
<td>Services (Operational and research) Agrometeorological information services for cereal production</td>
</tr>
<tr>
<td>4</td>
<td>Ecuador - A case study in agrometeorology</td>
<td>Manual Carvajal Ecuador, RA III</td>
<td>Report on various agromet. services: frost control, crop production, flowers, bulletins</td>
<td>Services (Operational) Farmers’ advisories</td>
</tr>
<tr>
<td>5</td>
<td>ISOP - Assessment of forage production variability over France</td>
<td>Ms. Victorine Pérarnaud France, RA VI</td>
<td>Report on integrated system (ISOP) for assessment of forage production over France</td>
<td>Services (Research) Government information systems</td>
</tr>
<tr>
<td>C.</td>
<td>Fully documented Case Studies received in response to initiatives taken by CAgM AWG members (April 2001)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Combating desertification and reintroducing agricultural production</td>
<td>Submitted by C. J. Stigt, The Netherlands, L.O. Z. Onyewotu, and J. J. Onowu, Nigeria, RA. 1</td>
<td>TTMI-Project of planting multiple shelterbelts as a strategy for controlling desertification in Sahelian conditions</td>
<td>Impacts (Research) Agromet research into returning to production on sandy soils reclaimed from wind driven desertification.</td>
</tr>
</tbody>
</table>

\(^1\)For details on Open Programme Area Groups (OPAG) see Circular letter No.4 of the President of CAgM
| 7 | Use and design of shelterbelts and scattered trees for protecting agricultural production | Submitted by C. J. Stigter, The Netherlands, Ahmed Eltayeb Mohammed, and Nawal K. Nasr Al-amin, Sudan, RA 1 | TTMI-Project of local solutions to problems caused by wind in Africa using trees in an agroforestry setting. | Impacts (Research) Agromet research into air movement around shelterbelts to develop shelterbelts design rules for sand encroachment protection |
| 8 | Improved underground grain storage microclimate | Submitted by C. J. Stigter, The Netherlands, Ahmed el-Tayeb, Sudan, RA 1 | TTMI-Project - traditional techniques of microclimate improvement by designing shallow pits, using chaff linings and constructing wide surface caps. | Impacts (Research) Increased climate variability encouraged farmers to experiment with possible improvements of underground storage pits for sorghum grain. |
| 10 | Water waste in traditional and more recently developed on-farm irrigation management in the Gezira Scheme | Submitted by C. J. Stigter, The Netherlands, Ahmed A. Ibrahim, and Hussein S. Adam, Sudan, RA 1 | TTMI-Project - to quantify water losses and water use efficiencies (sorghum and groundnut) under traditional attended) and newly evolved (unattended) watering methods. | Impacts (Research) Agromet research into quantitative on-farm water waste under different irrigation managements. |
| 11 | The U. S. Drought Monitor | Donald A. Wilhite and Mark D. Svoboda, USA, RA IV | An operational drought monitoring system for the USA | Services (Operational) (Media, agricultural producers, governments) |
| 12 | The Weekly Weather and Crop Bulletin Serving U. S. Agriculture | Thomas L. Puterbaugh and Bradley R. Rippey USA, RA IV | Highlighting weekly meteorological and agricultural developments on a national and international scale | Services (Operational) (Media, agribusiness, governments, farm organizations, crop and livestock producers) |
## D. Contributions received but not edited and not in a format suitable for Case Studies (for information only)

<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Author(s)</th>
<th>Description</th>
<th>Status Report</th>
<th>Impact Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>Drought and desertification in Uzbekistan</td>
<td>Vladimir Usmanov, Uzbekistan RA II</td>
<td>Unedited summary report based on 1999 Uzbekistan’s submission to UNCCC. For information only included as Annex 13 but no abstract.</td>
<td>Impacts (Operational) Status report on Uzbekistan situation re: desertification, degradation of natural resources, conversion of eco-systems and recommendations on climate adaptation.</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Agrometeorological products and their economic benefits in the Russian Federation</td>
<td>Ms. Olga Ustinova, Russian Federation RA VI</td>
<td>Unedited summary report (only title added and minor format modifications made by Co-ordinator) For information only included as Annex 14 but no abstract</td>
<td>Services (Operational and Research) Status report on agrometeorological services and applications in the Russian Federation</td>
<td>Services (Research) Agromet research into crank cancers in red oaks and mapping disease hazard in France</td>
</tr>
<tr>
<td>15</td>
<td>Mapping ink disease hazard for oaks in France</td>
<td>Ms. Victorine Péranoud, France, RA VI</td>
<td>Submitted 1-paragraph summary and 1-page poster in colour, but no other documentation. Summary for information only included as Annex 15.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2

Case studies submissions by WMO Regional Associations (RA) and CAgM Open Programme Area Groups (OPAG)

<table>
<thead>
<tr>
<th>WMO Regional Association</th>
<th>Services</th>
<th>Support Systems Observations, data, information, technological support</th>
<th>Impacts Priority issues: climate change, climate variability, and natural disasters</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA 1 Africa</td>
<td>2. Cowpea cultivation (Bénin)</td>
<td></td>
<td>6. Desertification (Nigeria)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7. Shelterbelts (Sudan)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8. Grain storage (Sudan)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9. Alley cropping (Kenya)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10. Water waste (Sudan)</td>
</tr>
<tr>
<td>RA 2 Asia</td>
<td></td>
<td></td>
<td>3. Agromet services for cereal production (Kazakhstan)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>13. Drought and desertification (Uzbekistan)</td>
</tr>
<tr>
<td>RA 3 South America</td>
<td>4. Agrometeorology Case Study (Ecuador)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RA 4 North and Central America</td>
<td>11. Drought Monitor (USA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>12. Weather and Crop Bulletin (USA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RA 5 South-West Pacific</td>
<td>1. Farmweather (Australia)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RA 6 Europe</td>
<td>5. ISOP-forage production variability (France)</td>
<td></td>
<td>14. Agrometeorological products (Russian Federation)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>15. Mapping ink disease for oaks (France)</td>
</tr>
</tbody>
</table>

The numbers in the body of the table refer to the number of the Case Study described in the text and in Table 1 of this Report.
Appendix I

Expert Group for Collection of Case Studies
of Economically Beneficial Agrometeorological Applications and Services
and other Success Stories in Agrometeorology for Policy Matters

Dr Wolfgang Baier (Co-ordinator)
Honorary Research Associate
Eastern Cereal and Oilseed Research Centre
Agriculture and Agri-Food Canada
OTTAWA Ontario K1A 0C6
Canada

PHONE: 1 613 820 5362
FAX: 1 613 759 1924
E-MAIL: wbaier@sympatico.ca

Memos sent:
16 February 2000
23 February 2000
17 May 2000
5 July 2000
1 September 2000
1 January 2001
1 June 2001
11 January 2002
15 February 2002
28 February 2002 (Final)

Mr Vladimir S. Antonenko
Prospect Naouki 37
KIEV 28
Ukraine

PHONE: 380 44 265 86 64
FAX: 380 44 265 53 63
E-MAIL: v_antonenko@kise-ua.com

Use e-mail
No report available

Mr Manuel Carvajal Ortiz
Departamento Agrometeorologia
Instituto Nacional de Meteorologia
e Hidrologia (INAMHI)
Inaquito No. 700 y Corea
QUITO
Ecuador

PHONE: 593 2 433936
FAX: 593 2 433934/456728
E-MAIL: carvajal@inamhi.gov.ec

Use e-mail
Final report included
See Table 1, B-4 and
Annex 4
Lyubov V. Lebed, Ph.D
Kazakh Scientific Research Institute for Environmental Monitoring and Climate of "Kazhydromet" State Enterprise
Seifulin pr., 597
480072 ALMATY
Republic of Kazakhstan

PHONE: : (7) 3272 62 57 93
E-MAIL: Llebed@softhome.net

Mr Gray Munthali
Senior Meteorologist/Head, Agrimet
Meteorological Department
Ministry of Transport
Meteorological Services
P.O. Box 2
CHILEKA
Malawi

FAX: 265 692 329
PHONE: 265 692 333
E-MAIL: malawimet@malawi.net

Ms Binh Nguyen Thi Thu
Hydrometeorological Service of Viet Nam
No. 4 Dang Thai Than Street
HANOI
Vietnam

PHONE: 84 48 357487

Mrs Victorine Pérarnaud
Responsable de la subdivision Agromet
SCEN/Services/Agrométéorologie
42 Avenue Coriolis
31057 TOULOUSE Cedex
France

PHONE: 33 5 6107 8381
FAX: 33 5 6107 8079
E-MAIL: victorine.perarnaud@meteo.fr

Final report included
See Table 1, B-3 and Annex 3

Use e-mail
No report available

Use mail
No report available

ISOP case study included. See Table 1, B-5 and Annex 5
Poster Mapping ink disease not included
See Table 1, D-15 and Summary in Annex 15
Dr Shuanghe Shen
Associate Professor/Deputy Chairman
Department of Applied Meteorology
Nanjing Institute of Meteorology
Nanjing, P.O. Box 210
JIANGSU PROVINCE 210044
China
PHONE: 86 25 7791336-2191
FAX: 86 25 7010085
E-MAIL: shensh@public1.ptt.js.cn

Mr Denis Tohio
Chef, Bureau d’Agrométéorologie
Service météorologique
BP 379 COTONOU
Bénin
PHONE: 229 30 14 13
FAX: 229 30 08 39
E-MAIL: tohiodenis@avu.org

Dr. Vladimir Usmanov
SANIGMI
K. Makhsumov, 72
K. TASCHKENT 70052
Uzbekistan
PHONE: 998 71 133 2025
FAX: 998 71 133 2025/1331150
E-MAIL: sanigmi@meteo.uz

Ms Olga Ustinova
Head of Marketing Researches Laboratory
ARRIAM
Lenin Street, 82
249020 OBNINSK Kaluga Region
Russian Federation
PHONE: 7 084 3971497 (71492)
FAX: 7 084 3971446 or 7 095 255225
E-MAIL: cxm@obninsk.ru
Dr. Petrit Zorba
Chief,
Agrometeorological Section
Hydrometeorological Institute
Dr. Durrest, Z. P. 219
TIRANA
Albania

PHONE: 347 487 5033
FAX: 355 42 38214/23518
E-MAIL: aspetalb@yahoo.com

Mr Richard N. Whitaker
NSW Manager, Special Services Unit
Bureau of Meteorology
P. O. Box 413
DARLINGHURST
Australia

PHONE: 61 2 92961563
FAX: 61 2 92115297
E-MAIL: richardw@bom.gov.au

Prof. Kees (C. J.) Stigter, Ph.D.
TTMI/African Network Liaison Office
Department of Environmental Sciences
Wageningen University and Research Centre
Duivendaal 2
6701 AP WAGENINGEN
The Netherlands

PHONE: 31 317 483332/3981
FAX: 31 317 482811
E-MAIL: Kees.stigter@User.METAIR.WAU.NL

Dr. R. P. Samui
Director, Agricultural Meteorology
India Meteorological Department
Shivajinagar, PUNE - 411 005
India

PHONE: 5535211, 5535245
FAX: 1613 759 1924
Dr. Donald A. Wilhite
National Drought Mitigation Center
International Drought Information Center
Professor, School of Natural Resource Science
241 L W. Chase Hall
University of Nebraska
Lincoln, Nebraska 68583-0749
USA.

PHONE: 402 472-4270
PHONE: 402 472-6707 (NDMC secretary)
FAX: 402 472-6614
E-MAIL: dwilhite@unlnotes.unl.edu

Thomas L. Puterbaugh
Supervisory Agricultural Meteorologist
USDA/OCE/WAOB/JAWF
1400 Independence Ave. SW
Washington, D. C. 20250-3812
USA

PHONE: 202 720 2012
FAX: 202 690 1805
E-MAIL: TPUTERBAUGH@mailoce.oce.usda.gov

cc Dr. Raymond Motha, President CAgM
   Dr. M. V. K. Sivakumar, Chief Agmet WMO
ANNEXES

Experts for Collection of Case Studies
of Economically Beneficial Agrometeorological Applications and Services
and other Success Stories in Agrometeorology for Policy Matters

Prepared by Co-ordinator of the Experts Group
Dr. Wolfgang Baier, Canada

Contents

1. Farmweather - a Case Study in Agrometeorology
2. Report on a case study of economically beneficial agrometeorological applications for cowpea cultivation
3. A few examples of agrometeorological services for cereal production in Kazakhstan
4. Ecuador - a case study in Agrometeorology
5. ISOP - An integrated system to real-time assessment of forage production variability over France
6. Combating desertification and reintroducing agricultural production by appropriate planting and multiple shelterbelts in Sahelian conditions and some simple agronomic measures
7. Use and suitable designs of shelterbelts and scattered trees as well as grasses for protecting agricultural production and infrastructure from wind driven sand encroachment and expanding desertification
8. Improved underground grain storage microclimate in cracking clay extended safe storage time by designing shallow pits, using chaff linings and constructing wide surface caps
9. Testing alley cropping (contour hedgerows) in semi-arid areas on flat and sloping land: soil and water conservation, competition, yields and economic factors
10. Water waste in traditional and more recently developed on-farm irrigation management in the Gezira Scheme in Central Sudan
11. The U. S. Drought Monitor
12. The weekly weather and crop bulletin serving U. S. Agriculture
13. Drought and desertification in Uzbekistan
15. Mapping ink disease hazard for oaks in France

Note by the Co-ordinator: the 16 Annexes were originally prepared by the contributors using different computer operating and word processing systems. Attempts to harmonise the formats were not entirely successful. Flaws in the appearance of the output format are possible and should be corrected locally, if necessary.
Annex 1

Farmweather - a Case Study in Agrometeorology

Abstract

In 1991, meteorological staff from the Australian Bureau of Meteorology toured the cotton growing areas of northern New South Wales, conducting interviews with cotton farmers and other farmers from surrounding areas. The combination of the expertise of the meteorologist and farmer resulted in the formation of the ?Farmweather? service which now provides weather forecast and agronomic advice to a large part of agricultural Australia. In 1996 and 1997, surveys were issued to a wide area of rural Australia to determine the impact of the ?Farmweather? service and revealed that the economic benefits based on only the production of four main export crops (wheat, cotton, barley and sorghum) were about six times the cost of producing the services.

Agrometeorological Service or Success Story

1. Background

Operational and strategic use of weather and climate information is important for agricultural producers for the profitable production of many commodities. Intelligent use of such information, based on advance knowledge of weather events can also contribute towards the goal of sustainable agricultural production through optimal use of chemicals and water.

Advancements in the science of meteorology, and in the development of computer hardware and software, such as supercomputers, satellite and radar technologies, have resulted in considerable improvements in global circulation models, the prediction of weather events, and the provision of meteorological and hydrological services such as locality specific weather services. In addition, the use of microcomputers, cable television, phone facsimile and global computer-based Internet information has greatly improved the accessibility of meteorological services, allowing more detail to be included in the forecast, as well as increased frequency of updates.

In Australia, delivery of forecasts to rural areas has, until recent times, relied almost exclusively on the media. Originally, distribution was via the mainstream newspapers, and then radio became important from the 1920’s, followed by television after 1956. This system of distribution largely controlled the style and information content of rural forecasts, with media restrictions on broadcast time and newspaper space always of paramount importance.

In November 1991, staff of the Australian Bureau of Meteorology conducted a tour of the cotton growing areas of New South Wales, during which numerous interviews were held with growers and farmers from the surrounding area. The idea was to gain feedback on how the existing rural forecast services could be improved, both in terms of forecast content and also mode of delivery.

The main issues raised in the meetings in priority order were:

1. More detail in the forecasts was requested, especially in the "further outlook" period from 48 to 120 hours ahead. A statement of forecast confidence was also requested, together with a quantitative estimate of precipitation amounts.
The preference for a "plain English" in normal conversational style was expressed. Phrases such as "mainly dry" or "becoming unsettled" are of only limited assistance in farm management strategies.

A graphic display of prognostic charts and expected rainfall distribution was requested to augment the text description of the forecast.

A more flexible method of forecast distribution was also asked for. An "on demand" service was considered ideal, rather than having to fit in with existing media programming schedules.

It was decided that these requests would be incorporated into a new forecasting service for the cotton growing regions of northern NSW, which we called "Cottonfields". Some additional agronomic advice involving evaporation trends and cotton degree days was also to be included during the period when cotton was actually in the ground.

The design of the service therefore arose directly from a combination of the expertise of meteorologist and farmer, resulting in an integrated forecast system produced explicitly to assist with short term farm management strategies.

**2. Description of the Service**

"Cottonfields" was designed to provide forecasts up to 7 days ahead, and consisted of three pages. These were a recent satellite photograph, a graphics page showing prognostic and rainfall predictions out to 4 days ahead, and a text page providing "expert opinion" commentary on the situation. This text page also contains information on forecast confidence, and quantitative rainfall predictions based on numerical model output.

In addressing the distribution problem, it was decided that this should be a non-media service, and a pollfax system was utilised. No national pollfax system existed at this time, so a local network was organised, centred on the fax machine located at the Namoi Cotton Cooperative offices. The forecast information was prepared at the Sydney Offices of the Bureau of Meteorology and then faxed to the Namoi Cotton Co-operative machine.

Cotton growers could then poll the information as required, and records of the demand for the service were also available as output from the Namoi fax machine. The service became operational in October 1992, with the demand immediate and heavy, and growers complained of the extensive delays encountered because of line congestion.

Another issue that emerged very early was the way the demand quickly spread beyond the farm gate, with polling requests being received from rural businesses, banks, commodity traders, transport companies, local media and international sources, as well as the local growers it was designed to service. Numerous requests were also received from farmers in adjacent parts of New South Wales to begin a similar service for their area, and it soon became apparent that there was a national demand for this type of service. It was then decided to launch a national fax delivered rural service under the umbrella name of "Farmweather", and delivery of this was to be achieved through the just developed Infotax system operated by Australia's national telecommunications company, Telstra. "Farmweather" commenced in July 1993, and was subsequently extended to cover 21 agricultural areas around Australia.
3. Growth of the Service

After about 1 year of operations, several usage patterns emerged. It became obvious that the demand for "Farmweather" was linked to three main factors, and these in total provided a measure of the level of rural activity around Australia. These factors are:

(a) Significant Weather Events

Whenever significant weather events occur anywhere in Australia, there is immediately a peak in the demand for "Farmweather" services from the affected area. Weather such as tropical cyclones, scattered thunderstorms, or a widespread rain event will trigger such a situation.

(b) Seasonality

Because of the climatic characteristics of Australia, agricultural activity is seasonal in many areas. In Western Australia, the main activity centres around the winter wheat crop, which is a direct result of the winter maximum/summer minimum rainfall pattern across the area. In Queensland, the situation is reversed, with a summer rainfall maximum resulting in peak agricultural activity between December and March, and a minimum during the winter months. In NSW, dual rainfall peaks occur, one in summer and the other in winter, and this produces two periods of maximum activity in agriculture. These facts show clearly in the call numbers in "Farmweather" with the pattern very pronounced in Western Australia and Queensland, and even the double peak for NSW emerges.

Attachment 1: Weekly Infofax calls - NSW - May 1994 to June 1996

The graph shows the weekly number of Infofax calls for New South Wales for the period May 1994 to June 1996, with the approximate line of average depicting the double annual peak referred to. So to a large extent, "Farmweather" call numbers produce a graph similar to the average rainfall pattern for the area in question.

(c) Awareness of the service

For the first 4 years, "Farmweather" call numbers grew steadily, and then peaked during 1999. Typically we now receive about 17,000, to 20,000 calls per month and from survey evidence, awareness of the service is now very high across rural Australia.

4. Example of a "Farmweather" service

Attachment 2: An example of the “Cottonfields” service

(a) Sheet 1 contains expert opinion text referring to the local weather forecast for the next seven days ahead, percentage probability of rainfall, temperature and wind forecasts, and the last three months Southern Oscillation Index.

(b) Sheet 2 contains forecast temperature and evaporation trends, accumulated cotton degree days compared with the same period last year, and the rainfall across the local area over the previous 24 hours.

1The three attachments are not included in this report but are available upon request from the Case Studies Co-ordinator
5. Assessment of the Service

During 1996, a detailed survey study of user's evaluation of the "Cottonfields" weather service and its related benefits to the Australian economy was undertaken (Anaman and Lellyett, 1996a, 1996b). Some of the key results were that the users generally considered the service to be of high quality and useful for both their farming and non-farming activities. The benefits to the Australian economy in terms of aggregate producer benefits (producers surplus) was based on the estimated one percent reduction of costs of producing cotton determined from the survey.

This yielded a societal benefit-cost ration of about 12:1 based on an increase in production of raw cotton (destined for export) resulting from the use of this service. However, with the advent of the "Farmweather" service, there was an obvious need to evaluate the national economic impact rather than just the effect on the cotton industry via the "Cottonfields" service. Consequently, in 1997, a survey was issued to a wide variety of farmers around Australia containing a large number of questions relating to the "Farmweather" service.

Attachment 3: Copy of the 1996 survey issued to cotton farmers in 1996 to determine their reaction to the "Cottonfields" service

The survey consisted of a questionnaire addressing the following issues:

(a) General farm information  
(b) Using weather information from the Cottonfields weather service.  
(c) Benefits of the Cottonfields weather information service.  
(d) Socio-economic characteristics of respondents.

The objective of this study was to analyse the use of "Farmweather" services and estimate the associated benefits to the Australian economy based on the production of several key export crops. The results of the survey were subject to standard economic regression analysis, and the associated economic theory and mathematical formulae can be found in Appendix 4 of the overall report: Assessment of the Australian Bureau of Meteorology's "Farmweather" Facsimile Services (Anaman 1997).

Economic Benefits of Service and/or Policy Matters Served

The investigation revealed that the economic benefits of the services based on only the production of four main export crops (wheat, cotton, barley and sorghum) were about six times the cost of producing the services.

"Farmweather" is therefore an economically viable service to the Australian rural economy. However, the actual benefits form "Farmweather" are probably considerably higher, because the survey did not include input from "beyond the farm gate" users, such as rural businesses, banks, commodity traders, transport companies and the media. It is reasonable to assume that these groups derive benefits similar to the farmers themselves.
Other Important Issues

The promulgation of an "expert opinion" weather forecast service, linked to graphically presented forecast information and satellite imagery, and available on demand, was perceived to be a significant step forward by rural Australia, and many appreciative references were received from the users.

(a) One of the first noticeable effects was a reduction in telephone requests from cotton growers to the NSW Regional Forecasting Centre. These calls were originated because farmers had difficulty in building up a coherent weather picture from the traditional media presentations. With "Cottonfields" providing the required level of detail, the demand for personal telephone briefings by a meteorologist fell, thereby allowing the forecasting team to concentrate more on the evolving meteorological situation.

(b) We became aware of the strong educational benefits of the service, with many requests for further information being received from schools. Because of its easy accessibility and user-friendly style, "Farmweather" was used in school projects, and also increased community awareness of the capabilities of a modern weather service. This capability was often obscured in media presentations.

(c) "Farmweather" allowed us to quantify the demand for our rural weather forecast services which is not possible through media delivery.

(d) Since the beginning of "Farmweather", the Internet revolution has broken, and "Farmweather" will soon be available through this source, incorporating live radar, satellite photograph "loops", and output from automatic weather stations. We now regard the fax machine as an intermediate step between the media and the Internet. Although the Internet is growing quickly in rural Australia, it is thought that demand for fax delivery will still be strong for the next two to three years.

(e) A possible advantage of "Farmweather" is that it can be useful in developing countries where Internet delivery is concentrated mainly in the cities, but which have a fax infrastructure extending to the rural areas. For example, there may be a police station or government office with a fax machine in many rural villages, and these could act as distribution or display points for a "Farmweather" type service. Once again we could view this as an interim step before general provision through the Internet.

(d) There has been considerable speculation in meteorological circles that the provision of such information as live radar, recent satellite photography and automatic weather station information will reduce the demand for the services of a meteorologist, and that user groups will merely attempt their own forecasts. Our experience with "Farmweather" has led us to a different conclusion. We have found that the more information provided, the more the demand for an expert opinion to integrate the data is produced.

Conclusion

The provision of a rural weather forecasting service covering the period out to one week ahead, incorporating the expert opinion of a meteorologist, computer graphics depicting model output, updated once per day, and including a recent satellite photograph, all available on demand, produces a quantifiable economic benefit to the rural activities of the host country. Delivery can be through pollfax or Internet
References


Resource person

Richard N. Whitaker,
NSW Manager, Special Services Unit,
Bureau of Meteorology,
P.O. Box 413, DARLINGHURST, N.S.W. 1300
Australia.
I- Introduction

Cowpea is a very important subsistence crop and is part of several foodstuffs found in Africa south of the Sahara. It is a leguminous plant with seeds that are very rich in protein. Like most crops, cowpea is subject to climatic hazards and plays an important role in low-lying soil cropping systems in the dry savannah and Sahelian regions, where most crops fail.

Unfortunately, cowpea is highly susceptible to insects, diseases and parasitic weeds, and is consequently very difficult to grow without using pesticides. Technical advice given to producers has led to a substantial improvement in cowpea production, but this increase is only possible when the plant’s requirements are taken into consideration.

I-1 Climatic requirements

I-1-1 Temperature requirements

Cowpea requires an average temperature between 25°C and 28°C during its vegetative cycle. Cowpea seeds can germinate between 10°C and 40°C, but the optimal temperature for this stage is between 15°C and 30°C. Cowpea is very sensitive to the cold and the growth of young plants is jeopardized at low temperatures (5°C).

I-1-2 Light requirements

Cowpea is a tropical plant with varying light requirements. The different varieties of cowpea, whether they be of short, medium or long duration, appear to adapt well to the various growing zones.

I-1-3 Water requirements

Cowpea requires between 300 mm and 600 mm of rainfall. A lack of water combined with excess heat can cause plants to wilt or even stop growing. A high level of humidity can also damage crop growth as it favours the development of many diseases and insects, and can also affect crop storage.

In conclusion, several climatic factors affect cowpea cultivation, but they work together in a combined form (such as water balance), which has a more significant effect than any single factor, such as water.

I-2 Soil-related requirements

Cowpea has a great ability to adapt to different soil types, whether they be sandy, clayey, fertile or less fertile. Cowpea is best suited to slightly acidic soils that are sufficiently light, well drained and provided with easily absorbed nutrients.
I-3 Pesticide requirements

Insect pests damage cowpea at all stages of its growth. Although the range and population of pests vary slightly from one site or region to another, a number of pests are characteristic of the ecosystems in which cowpea is grown throughout the world. Climatic conditions determine the population size of these pests, which are classified into several categories and attack the plant at the seedling and reproductive stages, and at the end of reproduction. The final category of insect pests that practically destroy the entire harvest attack whilst the crop is in storage.

II- Example of an economically beneficial agrometeorological application for cowpea cultivation

This study was carried out as part of the agrometeorological project. The experiment took place in a rural environment. The aim was to show farmers how agrometeorological applications could improve their production. The experiment involved establishing experimental plots of land at sites in rural areas.

II-1 Aim of the experiment

The experiment involved using experimental plots in rural areas to develop an agrometeorological information system and to disseminate this information amongst farmers with the help of the agricultural extension service. Its aim was thus to demonstrate the impact of agrometeorological parameters on cowpea cultivation and to convince farmers of the importance of taking agrometeorological information into consideration, along with the technology already popularized by the bodies responsible for rural development.

II-2 The experiment

Each farmer had a 1-hectare field divided into two parts: A and B. On plot A (the Control Plot), the farmer worked according to his usual methods.

On plot B (the Monitoring Plot), the farmer followed not only the instructions given by Rural Development Service officers but also those from the Agrometeorological Monitoring Team (a multi-disciplinary team composed of senior staff from the Meteorological Service and the Rural Development Services).

A Control Plot B Monitoring Plot

II-3 Advice given by the Monitoring Team

The advice given by the Monitoring Team mainly related to the agricultural calendar and pesticides. Advice was formulated according to:

- Meteorological observations, for example, rain, temperature, wind, relative humidity and evaporation, which came from the station nearest to (no more than 10 km) the experimental plot;
- Phenological observations carried out on the plots.

On each of these plots, four random 5 m x 5 m plots were determined, in which ten plants were sown and marked for observations. At harvest time, only produce found in the four square plots were taken into consideration for calculating the yield.
After each ten-day period, observations were sent to the Monitoring Team via SSB radio, telephone or the post. These analyzed data were then used to prepare advice according to the methods described below:

II-3-1 Soil preparation / sowing

Farmers were advised to prepare the soil two to four weeks before the beginning of the favorable sowing period (period determined by the P. Franquin method) and to sow after the first significant rainfall within the favourable sowing period. The sowing date has a significant effect on the cow pea emergence rate, since late sowing produces a higher observed emergence rate during the first five days of emergence. However, the farmers were advised to sow at the beginning of the season to limit infestation levels.

II-3-2 Weeding

Host plants parasitize cowpea crops. Particular attention is therefore given to monitoring weeds. As soon as weeds are observed, the period with the least amount of rainfall is statistically determined and, since weeding followed by heavy rainfall favours regrowth, weeding is confined to this period.

II-3-3 Spreading fertilizer

Since cowpea is a leguminous plant living in symbiosis with nitrogen-fixing bacteria, its cultivation does not require a nitrogen-based fertilizer. Nonetheless, other fertilizers, such as “supertriple” can be used. Ten-day monitoring of the water balance (FAO model) enables soil moisture reserves to be observed.

Fertilizing does not take place when soil is at its full water holding capacity. However, the Monitoring Team advised farmers to spread fertilizer just before the cowpea was sown, or just after its emergence, while ensuring that fertilizing did not take place when soil was close to its full water holding capacity, as more rain could lead to saturation and leaching which would take the fertilizer outside the range of the roots.

II-3-4 Pesticides

Pesticides were recommended as both prevention and treatment. The main emphasis was placed on preventive measures taking account of weather forecasts in relation to the behaviour of pathogenic agents. Since cowpea is susceptible to many parasites, increased and repeated doses of insecticides improve its yield. However, using insecticide is expensive and dangerous to both people and the environment.

Since the widest conception of agrometeorology is to protect the crop growing environment, the method recommended by the “ecologically sustainable plant protection methods of cowpea” project, which is coordinated by the IITA and carried out in collaboration with various national agricultural research bodies, can make cowpea production profitable, with minimum input costs, whilst causing only slight disruption to the ecosystem.

Environment-friendly systems are currently used in the following nine African countries: Benin, Burkina Faso, Mozambique, Niger, Nigeria, Cameroon, Ghana, Mali and Senegal.

For example, in Benin, Nigeria and Ghana, neem leaves (Azadirachta indica) or papaya (Carica papaya) are used as pesticides.
Liquid is extracted from the leaves of these plants and used as a pesticide (10 kg of leaves per 10 litres of water).

II-3-5  **Drying and preserving the produce**

Farmers usually dry cowpea seeds and obtain the necessary water content to be able to store them. At this stage, a solar device was recommended as part of the “ecologically sustainable plant protection methods for cowpea” project.

During the second drying stage, cowpea hay or dry bushes were placed on the ground and a black sheet spread over the top to act as a screen to stop solar radiation. The cowpea crop was spread out on the black sheet and then completely covered by a transparent sheet. A vacuum was created to protect the cowpea by rolling up the edges of the two sheets. The two-hour dying process took place between 11 a.m. and 1 p.m. Solar radiation passing through the transparent sheet was stopped by the black sheet, and consequently the temperature between the two sheets was very high (this heat eliminates any larvae and adult insects amongst the seeds).

To avoid re-infestation, the treated cowpea was put into plastic bags or sealed jars.

III-  **Results and Comments**

Comparing the yields at harvest time enabled the farmers to see the impact of advice given by the Monitoring Team. Being convinced that this advice was correct, the farmers tended to apply the instructions given for the Monitoring Plots to the Control Plots. Observations showed that the Monitoring Plots were significantly different when compared to the Control Plots.

The results obtained as part of the agrometeorological project were achieved using synthetic chemical products as pesticides. If natural products, as recommended in the above-mentioned “ecologically sustainable plant protection methods for cowpea” project, were used instead of these synthetic chemical products, this agrometeorological application would undoubtedly be economically beneficial and ecologically sustainable.

**Conclusions**

When agrometeorological applications are properly followed, they are often beneficial. However, in most cases, they are not used by most of the farming community, and are taking a long time to be popularized. They are often used primarily at sites where experiments have taken place.

**Bibliographical references**

2. Les Légumineuses à graines, Madagascar, 1988, par Prof. Y. Demarly.
5. Rapport final des expérimentations de la Campagne 1992, Projet PNUD/OMM, BEN 87/010, BENIN.


10. Agrometeorology of Groundnut.

Resource person

Mr Dénis Tohio
Chief, Agrometeorological Office
Meteorological Service of Benin
BP: 379 COTONOU
Tel.: (229) 30 01 48
Fax: (229) 30 08 39
E-mail: tohiodenis@AVU.org
Annex 3

A FEW EXAMPLES OF AGROMETEOROLOGICAL SERVICES
FOR CEREAL PRODUCTION IN KAZAKHSTAN

by Dr L. Lebed

Abstract

Cereal production is, along with livestock breeding, one of the main agricultural activities in Kazakhstan, which has an arid climate. According to statistical records, in the past 20 years the area planted with cereals has varied from 12 to 22 million hectares. Of this, 65 per cent is devoted to spring wheat, which is planted predominantly in the northern part of the country. The agroclimatic conditions for spring wheat vegetation in northern Kazakhstan generally include a sufficient amount of warmth (with between 2,000 and 3,000 degree days over $10^\circ C$) and a lack of moisture (annual precipitation ranges from 250 mm to 350 mm). When favourable agrometeorological conditions exist in the northern part of Kazakhstan, high-tech farming in chernozemic soils can produce spring wheat yields of up to 3.0 tonnes per hectare without the use of irrigation. However, if we take into consideration all types of farms, average yield in the oblasts is considerably lower, ranging from 0.2 to 1.3 tonnes per hectare. In the past decade there has been a decline in spring wheat yields and in total cereal yields in Kazakhstan. In order to support grain production, the national Hydrometeorological Service is now upgrading its agrometeorological information services.

Example 1: Spring wheat harvest forecasts and their effectiveness

1.1 Background forecast of average spring wheat harvest yield in the oblast.

The forecast method developed by the author (1,2) was drawn up for Kostanaiskaya, Severo-Kazakhstanskaya, Akmolinskaya and other oblasts of northern Kazakhstan (see figure 1).

![Figure 1: Administrative divisions of the Republic of Kazakhstan](image-url)
It is based on the Fedoseev moisture index (represented by $K$), which is presented below:

$$K_{\tau} = \frac{W_0 + \sum_{0}^{\tau} R}{a \cdot \sum_{0}^{\tau} D}$$  

(1)

where:

- $W_0$ is the moisture reserve in the soil for the spring, in mm;
- $R$ is the precipitation during the vegetation period, in mm;
- $D$ is the evaporation potential, in mm; and
- $a$ is an equation parameter.

Research has shown that there is a close correlation between crop yield and the moisture index at the ear formation stage of spring wheat. However, the lead time of harvest forecasts at the ear formation stage is just 1-1.5 months. Opportunities for agrometeorological forecasting of harvest yields prior to crop sowing in northern Kazakhstan are limited by the maximum summer precipitation, which often comes during the second half of the vegetation period. In this case, harvest yield forecasts formulated prior to the sowing of spring wheat can be considered only as preliminary background forecasts. Information on additional moisture from summer precipitation and the final amount of the harvest can be assessed probabilistically (table 1). As can be seen from the table, when there is a normal amount of precipitation in the vegetation period, good soil moisture reserves for the spring can ensure that there will be an average increase of 0.4 to 0.6 tonnes per hectare of spring wheat harvest in the oblasts. Also, if precipitation in the vegetation period is greater than normal, another 0.6 to 0.7 tonnes per hectare may be yielded. In some very wet years, the bonus from summer precipitation has come to 0.8 to 1.2 tonnes per hectare. The crop yield for spring wheat can thus reach the final value of 1.5 tonnes or more per hectare on average for the oblasts.
Table 1: Possible harvest yield of spring wheat in northern Kazakhstan taking into consideration the A. Fedoseev moisture index prior to sowing KtO and the possible precipitation distribution during the vegetation period

<table>
<thead>
<tr>
<th>Precipitation distribution during the vegetation period</th>
<th>Crop yield, tonnes per hectare</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>KtO=1.0-1.4</td>
</tr>
<tr>
<td>May-July ? normal</td>
<td>0.3</td>
</tr>
<tr>
<td>May, May and June, June &gt; normal</td>
<td>0.3-0.6</td>
</tr>
<tr>
<td>July, June and July &gt; normal</td>
<td>0.6-0.8</td>
</tr>
<tr>
<td>May-July &gt; normal</td>
<td>0.9-1.2</td>
</tr>
</tbody>
</table>

1.2 Spring wheat yield forecasting based on a dynamic-statistical model of cereal yields

This method was drawn up by two co-authors (2, 3). It provides for calculations of light (CS), heat (CT) and moisture (CW) for spring wheat plants as part of the dynamic for the vegetation period, and for the calculation of warm, dry wind influences (CD) and expected harvest yields (Yt). The results of the calculations are shown in table 2. The contribution to the crop yield of the agrotechnical factor, YA, is calculated on the basis of multiple-year harvest yield trends.

Table 2: Assessment of agrometeorological conditions of spring wheat vegetation and expected cereal harvest crop yields, 1998-2001 trends for Akmolinskaya oblast, northern Kazakhstan

<table>
<thead>
<tr>
<th>Year</th>
<th>Calculation period</th>
<th>Agrometeorological conditions, assessment of 1 (unit)</th>
<th>YA tonnes per hectare</th>
<th>Yt tonnes per hectare</th>
<th>Control Y tonnes per hectare</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CW</td>
<td>CT</td>
<td>CD</td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>21 June</td>
<td>0.71</td>
<td>0.79</td>
<td>0.76</td>
<td>0.81</td>
</tr>
<tr>
<td>1999</td>
<td>21 June</td>
<td>1.66</td>
<td>1.00</td>
<td>1.00</td>
<td>0.77</td>
</tr>
<tr>
<td>2000</td>
<td>21 June</td>
<td>1.25</td>
<td>0.94</td>
<td>1.00</td>
<td>0.76</td>
</tr>
<tr>
<td>2001</td>
<td>21 June</td>
<td>0.90</td>
<td>-</td>
<td>-</td>
<td>0.76</td>
</tr>
<tr>
<td></td>
<td>21 June</td>
<td>0.86</td>
<td>1.00</td>
<td>-</td>
<td>0.76</td>
</tr>
<tr>
<td></td>
<td>21 June</td>
<td>1.44</td>
<td>1.00</td>
<td>1.00</td>
<td>0.76</td>
</tr>
</tbody>
</table>

Cereal crop yield forecasts drawn up prior to sowing are economically very effective. By way of example, let us assess the effectiveness of the harvest forecast used for the conclusion of major contracts for the wholesale delivery (or purchase) of spring wheat at the oblast level. The assessment of the economic effectiveness of the harvest yield forecast is done according to Mr Y. Khvalensky’s formula, taken from reference work (3), as follows:

$$ EE = S^*K[(VM-Vt-VL)P1+(Vt-VR)P2-(VM-VF-VL)P1-(VF-VR)P2], $$  

(2)

where:

- EE is the economic effectiveness of the forecast, in thousand US dollars;
- S is the coefficient of the share represented by scientific information, in decimal parts of a whole;
- K is the adjustment coefficient for forecast validity;
VM is the possible volume of purchased cereals, in thousand tonnes;  
Vt is the actual cereal harvest, as determined from the harvest trend, in thousand tonnes;  
VF is the forecast cereal harvest, in thousand tonnes;  
VR is the actual cereal harvest as reported in statistics, in thousand tonnes;  
VL is the requirement for cereal, to meet the needs of the oblast (food, planting, planned State deliveries, etc.), in thousand tonnes;  
P1 is the price of the cereal at the time of forecast, in US dollars per tonne;  
P2 is the price of the cereal after the actual harvest, in US dollars per tonne.

Table 3 presents a few results of the potential economic effectiveness of spring wheat harvest forecasts if they are used when cereal purchase contracts are concluded in years with various agrometeorological conditions. The information base for the calculation of the economic effectiveness of the forecast is data from average multi-year trends in harvests, statistical data on the harvest and acreage planted in spring wheat and the official prices for the cereal, which are set in Kazakhstan at the time of sowing and harvest for the years in question. As the calculations show, the economic effectiveness of the harvest forecasts as a function of agrometeorological conditions can change by a factor of several times from one year to the next. The greatest effect of the harvest forecast can be achieved in years with weather anomalies.

### Table 3: Potential economic effectiveness of harvest forecasts for spring wheat (Kostanajskaya oblast taken as an example)

<table>
<thead>
<tr>
<th>Source and calculated indices</th>
<th>Year</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Area under acreage, $10^3$ hectares</td>
<td>1995</td>
<td>1996</td>
<td></td>
</tr>
<tr>
<td>Volume of purchased cereal, $10^3$ T (VM)</td>
<td>2292</td>
<td>2234</td>
<td></td>
</tr>
<tr>
<td>Actual cereal harvest, as defined form the harvest trend, $10^3$ T (Vt)</td>
<td>4500</td>
<td>4500</td>
<td></td>
</tr>
<tr>
<td>Actual cereal harvest as reported in statistics, $10^3$ T (VR)</td>
<td>2384</td>
<td>1924</td>
<td></td>
</tr>
<tr>
<td>Forecast cereal harvest, $10^3$ T (VF)</td>
<td>1031</td>
<td>1854</td>
<td></td>
</tr>
<tr>
<td>Requirement for cereal to meet the needs of the oblast, $10^3$ T (VL)</td>
<td>715</td>
<td>2122</td>
<td></td>
</tr>
<tr>
<td>Price of the cereal at the time of forecast, US $ (P1)</td>
<td>400</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>Price of the cereal after the actual harvest, US $ (P2)</td>
<td>100</td>
<td>160</td>
<td></td>
</tr>
<tr>
<td>Economic effectiveness of the forecast, thousand US $ (EE)</td>
<td>16022</td>
<td>633</td>
<td></td>
</tr>
</tbody>
</table>

### Example 2: Assessment of spring wheat harvest increase reserves

The cereal harvest model makes it possible to calculate trends in the spring wheat harvest over many years, and to define possible reserves in actual cereal harvests for coming years. In figure 2, the analysis of trends in the spring wheat harvest shows that thanks to the agrotechnical factor alone, in the conditions prevailing in northern Kazakhstan, even in 2000 and 2001 the harvest could be increased by an average of 0.2 tonnes per hectare or more for the oblast. An increase in the harvest can be ensured by means of the expert application by cereal producers of local farming techniques, the use of mineral fertilizers and conditioned seeds, and other factors.
Figure 2: Multiple-year variation of average spring wheat harvest yields (tonnes per hectare) for Akmolinskaya oblast, northern Kazakhstan:

1: Harvest yield from statistical reporting
2: Harvest yield trend (n=10)
3: Harvest yield trend (n=16)

Example 3: Assessment of the effectiveness of the use of agroclimatic resources

Most cereal producers in northern Kazakhstan sow spring wheat in May or even in June. The late sowing is done with a view to enabling the plants to take advantage of the moisture from the so-called July precipitation maximum. In the opinion of agrometeorologists, there is no justification to expect an effect from the July precipitation. This is confirmed by the results of the modelling of agrometeorological conditions in the vegetation period and the determination of expected spring wheat harvests with various (assigned) sowing periods (4). An analysis of these results, which can be seen in table 4, shows that the most favourable moisture conditions for the sowing of spring wheat prevail 10 to 20 days prior to the usual sowing period. When the wheat is sown earlier there is also less danger of autumn frost damage. Only years with very dry months of May and June, with no rain, such as 1999 and 2001, are an exception which would argue for the late sowing of spring wheat. In northern Kazakhstan, a greater effect from the early sowing of spring wheat is to be expected when springtime comes early and there are sufficient soil moisture reserves prior to the sowing, such as in the conditions which prevailed in 1995, 1997 and 2000. The cereal crop yield in such conditions increases on average by 0.2 tonnes per hectare in the oblast.
Table 4: Change of agrometeorological conditions for the vegetation and possible crop yield of spring wheat with various sowing periods, using the example of Akmolinskaya oblast, northern Kazakhstan

<table>
<thead>
<tr>
<th>Year</th>
<th>Precipitation higher than normal in:</th>
<th>Possible sowing periods</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Last ten days of April, t, relative units</td>
<td>First ten days of May, t, relative units</td>
</tr>
<tr>
<td>May</td>
<td>June</td>
<td>July</td>
</tr>
<tr>
<td>1995</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>1996</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>1997</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>1998</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1999</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2000</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>2001</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

= optimal sowing period

Conclusions

Agrometeorological information is extremely important for consolidating and increasing cereal production in Kazakhstan. In this connection, agrometeorological forecasts of cereal harvest yields drawn up prior to crop sowing stand out because they are highly effective. Agroclimatic information, on the sowing periods of cereal crops, required quantities of mineral fertilizers, chemical plant protection measures and other farming techniques, can be highly effective as well. Agrometeorological information makes it possible to draw up the best strategy beforehand and to assess real incomes in production.

Literature

1. Lebed, L. V., Towards an assessment of harvest crop yield for spring wheat grown using intensive farming techniques in northern Kazakhstan, Hydrometeorological services fro the country's agro-industrial complex / Compendium of reports of the All-Union Meeting, Tselinograd, September 1988, Leningrad, Gidrometeoizdat, p. 49-53.


Resource person

Lyubov V. Lebed, Ph.D
Kazakh Scientific Research Institute for Environmental Monitoring and Climate of "Kazhydromet" State Enterprise
Seifulin pr., 597
480072 Almaty
Republic of Kazakhstan
Phone: (7) 3272 62 57 93
E-ml: Llebed@softhome.net
Ecuador - A case study in Agrometeorology

Abstract

The name of Ecuador is due to its geographical location over the equatorial line, it shows a minimal climatic variation during the year. We are using some applications of the agrometeorological data, the principal is related to sowing and harvesting calendar that has an historical and practical application in agriculture meteorology. However forecast and frost control have a minimal application. Since five years ago the farmers are using agrometeorological data especially about solar radiation and specifically about sunshine, they have obtained some advances to improve the yields. Reduction of forest fires has been a new application, but it needs to be improved. The agrometeorological bulletins (monthly and decade [10 days] ), is a tool for authorities and farmers, but it is necessary to redesign in order to obtain better results.

Agrometeorological Services or Success Stories

1. Background

The name of our country was given due to its geographical location over the equatorial line, it has many climatic conditions and with little spatial and temporal variation. Because of its multiple topoclimatology it has many altitudinal conditions from 0 to 19000 feet (highest mountain). These conditions make it possible to cultivate and obtain abundant crops and varieties.

The country has four "natural" regions: coastal, highlands, Amazonian and the Galapagos Island.

The climatic classification of the coastal and Amazonian region was made considering the heat index and shows different climates: hyperhumid, humid, subhumid, semiarid and dry, the last two belongs to the islands. For the highlands the classification was made by evapotranspiration index: mesotermic, mycrotermic, tundra and glacial.

2. Description of the Services

2.1 Sowing and harvesting calendar

The country has a good climatic stability, the sowing and harvesting months had been identified since long time ago The baseline is the historical knowledge about the beginning of rainfall season sowing (October - December in highlands and December - April in coastal) and end of the rainy season (May - July and June August in the same order) period of harvesting. These calendars have an historical and practical applications in agriculture meteorology.

Another reason for the utility of calendar is to use efficiently the water resources during rainfall season, avoiding the need of supplementary irrigation.

2.2 Forecast and Frost Control

In the highlands the months of July and August are known to be most dangerous because of the high possibility of frost damage, so the farmers avoid cropping during this period, but some of them do the cropping under these conditions, they take the high risk to get better prices for their products, nevertheless they know little about these risk affect their crops.
3. **Other agrometeorological success**

In our country since 1995 we pay much attention agrometeorological information, using the climate as a resource and not like a menace, and also know how to manage the linking with technical practices in order to get better yields.

Finally we are getting and using the available information, especially about solar radiation, and specifically about sunshine. Using these information, the farmer has obtained some advances to improve the yields, as an example we could show some results in sugar cane (*Cannabis sativa*) and Oil palm (*Elaeis guineensis*).

### 3.1 Sugar Cane Success Story

The application of agrometeorological data permit to get better yields, thinking that 200 MT/ha is equal 100% in traditional areas, in the table we can see in the new areas an improvement from 5 to 10% in yields, considering that international prices approximately are $220 USD/MT, (New York and London Markets [2000]) so the benefit income is between $2000 to $8000 USD/ha.

#### Table 1. Sunshine influence in sugar cane yield

<table>
<thead>
<tr>
<th>Location (Sugar Industries)</th>
<th>Geographical position</th>
<th>Sunshine (hour/year)</th>
<th>Yield MT/ha</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>La Troncal</td>
<td>02° 22´ 27 S 79° 22´ 27 W</td>
<td>687</td>
<td>200</td>
<td>100 %</td>
</tr>
<tr>
<td>San Carlos</td>
<td>02° 12´ 00 S 79° 26´ 35 W</td>
<td>754</td>
<td>210</td>
<td>+ 5 %</td>
</tr>
<tr>
<td>Valdez</td>
<td>02° 06´ 56 S 79° 35´ 57 W</td>
<td>1010</td>
<td>240</td>
<td>+ 10 %</td>
</tr>
</tbody>
</table>

**Attachment 1**: Graphic 1. Showing the sunshine influence in sugar cane yield

### 3.2 Oil Palm Success Story

The application of agrometeorological data in order to choose the best location for a crop, in Oil palm, in the new location we can get an important yield improvement (around 60%), so if the International prices are next to $380 USD/MT, its meaning an increment from $2000 to $3000 USD/ha. The oil palm crops covers in surface more than 110 000 ha, and permit to work around 70 000 people in direct and indirect occupations.

#### Table 2. Sunshine influence in Oil palm yield

<table>
<thead>
<tr>
<th>Location</th>
<th>Geographical position</th>
<th>Sunshine (hour/year)</th>
<th>Yield MT/ha</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Santo Domingo</td>
<td>00° 00´ 15 S 00 W</td>
<td>605</td>
<td>13 -14</td>
<td>100 %</td>
</tr>
<tr>
<td>San Lorenzo</td>
<td>01° 16´ 06 N 00 W</td>
<td>1216</td>
<td>20 - 25</td>
<td>+ 60%</td>
</tr>
</tbody>
</table>

**Attachment 2**: Graphic 2. Showing the sunshine influence in oil palm yield
3.3 Tomato and "Babaco" Success Story

The growing of tomato (Lycopersicum sculentum) and "babaco" (Carica pentagona) has been made traditionally in the open field, nowadays it is cultivated indoors (greenhouse) under controlled environment conditions, in this way the yields have been amazing around 100 and 60 TM/ha versus 32 and 20 TM/ha in the traditional method, these production difference is approximately 300%, these increments translated to income benefit is very important.

Attachment 3: Graphic 3 Showing Comparative Yields between Field and Greenhouse production

3.4 Flowers Crops

In Ecuador, flower growing is 17 years old, the first crops were made in greenhouses, however the know how came from Colombians producers. The climatic parameter was not known until some years ago. Lately the producers are working under controlled conditions in greenhouses (surface around 2000 ha), so they have improved their production rates and their crop management.

<table>
<thead>
<tr>
<th>Year</th>
<th>1997</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Millions USD</td>
<td>131</td>
<td>162</td>
<td>180</td>
<td>193</td>
</tr>
</tbody>
</table>

3.5 Forest fires

This year the Institute began its participation in fire prevention, working together with municipal authorities, fire department, civil protection and the army, they are developing an alert system to avoid fires in the forests near the Capital city.

The INAMHI using meteorological information communicates the rainfall behavior and the level of probability of starting a forest fire. This objective has many activities: to make clear inhabitants about the benefits of preserving the natural environment and their active participation for fire control. In 1999 there were 317 forest fires that damage 75 has, in 2000 254 fires/ 60 has. We would like to improve our active participation to reduce those forest fires.

4. Agrometeorological bulletins

4.1 Decadal (ten days) bulletin

The decadal bulletin has prepared since 1985, and during all these years there have been many changes, the last editions contain information relative to rainfall forecasting for the next ten days, with information about how to get more economical crops for local use, as in potatoes, sea level and mountain corn, wheat, barley, vicia faba, soybean, rice and bean.

The bulletin has information regarding rainfall behavior with comparative assessments in function with the previous decade, the variability of this parameter in function with the historical normal and seasonal behavior, will help us to statistically calculate and obtain the forecast for the next ten days (decade).

The bulletin also provides analyses of extreme temperatures that could affect normal crop development, with certain thresholds for the coastal areas over 35°C and for highlands under 4°C. In both cases a kind of alert is issued.
The crops are analyzed by their phonological phases in relation with the weather conditions in which they develop, and the phase while the bulletin is prepared, and a calendar about sowing and harvesting times.

4.2 Monthly bulletin

The monthly bulletin depicts how each crop when it is almost ready for harvesting with climatic conditions forecasted for the next month. Some of the graphics show the rainfall behavior during the crops cycle compared with the water requirements for each one. Water balance data informs of an excessive or lack of rainfall, at the same time the temperatures are evaluated in order to know how they could affect the crops developing.

There are some tables that show the yields expecting with or without enough rainfall, these quantity is compared with the average historical yields obtained during the last years.

CONCLUSIONS

- The agrometeorological information in the country is very limited due to our geographical situation, the reason is that it shows a minimal climatic variation during the year.
- During the last years, the agrometeorological information became very useful for the agriculture sector and proved how beneficial is its management to obtain better yields.
- The sowing and harvesting calendar has had the oldest application for agrometeorological data.
- The bulletins are coordinated with Ministry of Agriculture and is sent to authorities who will take decisions, we are developing a new one for farmers, that will circulate next month. Since this year a radio bulletin is issued weekly for farmers, nowadays we are sending a questionnaire to its users, in order to improve its contents and utility.
- Finally, all the help that other experts can gives us will be greatly appreciated and warmly received. Agrometeorology is today hardly known in the country and its application is very limited.
References

2. BANCO CENTRAL DEL ECUADOR, Cadena agroindustrial de aceites y oleaginosas, septiembre 2000.
5. EXPORTADORES DE FLORES - EXPOFLORES, Índices de producción, octubre 2000
7. SERVICIO DE INFORMACION Y CENSO AGROPECUARIO - SICA/BM (Banco Mundial), Información de productos tradicionales y de exportación, 2001

Resource Person

Manuel Carvajal Ortiz
Instituto Nacional de Meteorología e Hidrología
Dpto. Agrometeorología
Iñáquito N14-36 y Corea
Telefax: 593 (2) 2456 728 / 2433 934
Email: carvajal@inamhi.gov.ec
Manocarv@yahoo.com
Attachment 1:

SUNSHINE INFLUENCE IN SUGAR CANE YIELD

Graphic 1: Comparative yield of sugar cane in different locations with different amount of sunshine per year.

Attachment 2:

SUNSHINE INFLUENCE IN OIL PALM YIELD

Graphic 2: Comparative yield of oil palm in different locations with different amount of sunshine per year.
Attachment 3:

Graphic 3: Comparative Yields between Field and Greenhouse production
Annex 5

ISOP: An integrated system to real-time assessment of forage production variability over France


* METEO-FRANCE, Agrometeorology, 42 av. G. Coriolis, 31057 TOULOUSE Cedex, France, phone: (33)561078388, fax: (33)561078079, email: Isabelle.Donet@meteo.fr
** INRA, Bioclimatology, Domaine Saint-Paul, Site Agroparc, 84914 Avignon Cedex 9, France, phone: (33)490316247, fax: (33)490316420, email: ruget@avignon.inra.fr
*** Ministry of Agriculture, Statistics, Complexe agricole d'auzeville, B.P. 88, 31326 CASTANET Tolosan Cedex, France, phone: (33)561288526, fax: (33)561288443, email: bsvf@agriculture.gouv.fr

Abstract

Since 1997, an integrated system called ISOP has been developed between three French participants: the ministry of Agriculture (through its Department of Statistics, SCEES), the institute for Agronomical Research (INRA) and the national meteorological service (METEO-FRANCE). The purpose is to produce reliable estimations of the forage production, in order to give objective information to the ministry of Agriculture to estimate real production losses in case of local or global drought. Input data are various and multiple, including special meteorological parameters, percentages of soil types, nitrogen status and amounts and frequency of mowing or grazing, estimated from a national survey. The STICS crop model is applied to three kinds of grassland: permanent, temporary and pure legumes. The results are available for 200 regions of forage production (RFP) and synthesised in alert maps and temporal graphs for selected drought-stricken areas.

This project started in 1997 [1] and a model was carried out in 1998 on 7 selected forage regions in the south-west of France to verify the feasibility and the accuracy of the ISOP system. This paper presents an overview of ISOP and some preliminary results.

Agrometeorological Service or Success Story

Main input data in ISOP

The model [2] is part of the multi-crop simulator STICS [3] and simulates the evolution of grass above ground dry matter and water and nitrogen balances. The current year assessed values will be compared with Reference values calculated as statistical values (fractiles) on the period 1982-1996 for each grassland type and each RFP.

The STICS crop model needs daily meteorological parameters (temperatures, rain, global radiation and PET). These data should be available for the reference period (1982 to 1996) and also for the current year to provide real-time outputs with a short delay. A preliminary study was carried out in 1998 to choose the best interpolation method (in terms of accuracy, robustness and quickness) between the ones available at METEO-FRANCE. Accordingly, the Inverse Weighted Distance method was selected to interpolate the ground meteorological measurements at the centroïd of each of the 200 RFP. Figure 1 presents an example for a daily PET interpolated input field for ISOP.
The management practices for mowing frequency and nitrogen supply are estimated from a national survey (8800 fields surveyed in autumn 1998) for the 182 (of 200) RFP with a representative grassland surface (more than 7000 hectares). The results were concentrated and stored by the Department of Statistics of the Ministry of Agriculture and then translated into direct inputs for the STICS crop model. These data concern values of thermal time between mowings, number of mowings, amounts of nitrogen supply during winter and spring, initial nitrogen indices. One of the parameters provided by the survey is shown in Figure 2, it corresponds to the average nitrogen supply per RFP.

To take into account the different soil types on which the grasslands are to be found, the EU (1/1 000 000) soil map is used to provide soil map units where only predominant soils are listed. These soils are then characterised by their water capacity and nitrogen mineralization properties per layer and introduced in the system.

Figure 3 shows one aspect of this soil map over France and demonstrates the complexity of this information.
ISOP operating overview

The STICS multi-crop simulator was tested, completed and calibrated by INRA in order to properly simulate the behaviour and the production of grassland over France. Available experimental data were used to achieve these calibration and adaptation of the crop model to the various spatially varying input data.

To assess the forage production at the country level and compare the values of the current year to statistics, the STICS crop model runs several times for each combination of soil, mowing frequency and nitrogen amount for each grassland type in each RFP, then the results are aggregated. These combinations are issued of both the national survey data and the soil map and are summed up in tables of input characteristic data. Figure 4 presents an example of these configuration tables, as applied for 1 of the 7 test RFP, with all coded input data for STICS.

Figure 4: Example of the 8 combinations for one RFP and one grassland type

<table>
<thead>
<tr>
<th>RFP number</th>
<th>Grassland type code</th>
<th>Simulation number</th>
<th>Simulation weight</th>
<th>Soil type number</th>
<th>Management practise code</th>
<th>Initial nitrogen index</th>
<th>Irrigation satisfaction index</th>
</tr>
</thead>
<tbody>
<tr>
<td>5410</td>
<td>48</td>
<td>1</td>
<td>10%</td>
<td>27</td>
<td>1</td>
<td>0.4</td>
<td>0</td>
</tr>
<tr>
<td>5410</td>
<td>48</td>
<td>2</td>
<td>11%</td>
<td>27</td>
<td>5</td>
<td>0.4</td>
<td>0</td>
</tr>
<tr>
<td>5410</td>
<td>48</td>
<td>3</td>
<td>13%</td>
<td>27</td>
<td>7</td>
<td>0.4</td>
<td>0</td>
</tr>
<tr>
<td>5410</td>
<td>48</td>
<td>4</td>
<td>22%</td>
<td>27</td>
<td>13</td>
<td>0.4</td>
<td>0</td>
</tr>
<tr>
<td>5410</td>
<td>48</td>
<td>5</td>
<td>12%</td>
<td>27</td>
<td>15</td>
<td>0.4</td>
<td>0</td>
</tr>
<tr>
<td>5410</td>
<td>48</td>
<td>6</td>
<td>16%</td>
<td>27</td>
<td>21</td>
<td>0.4</td>
<td>0</td>
</tr>
<tr>
<td>5410</td>
<td>48</td>
<td>7</td>
<td>8%</td>
<td>27</td>
<td>23</td>
<td>0.4</td>
<td>0</td>
</tr>
<tr>
<td>5410</td>
<td>48</td>
<td>8</td>
<td>8%</td>
<td>33</td>
<td>13</td>
<td>0.4</td>
<td>0</td>
</tr>
</tbody>
</table>

To cover France in the operational mode, about 6000 simulations are foreseen to cover the 182 (of 200) RFP. The calculation will be run automatically each ten-days period to allow the French ministry of Agriculture to obtain real-time information at request.

Main outputs of ISOP (issued from the model, applied to 7 RFP)

From all these simulations and output data stored on an operational way, two main products will be provided at the request of the ministry of Agriculture. Both will concern the relative values (ratio to mean production) of the forage production, aggregated for each RFP and each grassland type.

A prototype of ISOP, realised in 1998 on 7 selected RFP, allowed to verify the feasibility of such a complex system and validated the first outputs. The following results stemmed from this prototype.

The two examples shown in Figures 5 & 6 illustrate some products proposed for the operational monitoring. Figure 5 correspond to a national spatial overview of the potential drought-stricken areas, displaying the areas with the lowest production ratio. To complete the previous spatial information, on relevant RFP, temporal graphs can be achieved. Figure 6 describes the temporal effects of the drought and also its intensity and length.
ISOP accuracy should also be tested and comparison between the ISOP assessments and the expert SCEES data were realised on the limited model sample.

Figure 7 presents two samples of compared data between values predicted by ISOP for one RFP and the corresponding departmental expert data. At this step of the project, the results are encouraging. Such a validation will be repeated for the whole system at the end of 1999.

**Final steps in 1999 before the operational system**

The 1998 model, applied for 7 selected RFP, validated the ISOP system in producing relative values consistent with expert data. In 1999, the global system will be applied to the 200 regions and on the reference period *(i.e. since 1982)*. From the beginning of 2000, the ministry of Agriculture will obtain objective relative values of the current forage production on request.
References


Resource person

Mrs. Victorine Pérarnaud
Responsable de la subdivision Agromet
SCEN/Services/Agrométéorologie
Météo-France
42 Avenue Coriolis
31057 TOULOUSE Cedex
France
Annex 6

Combating desertification and reintroducing agricultural production by appropriate planting of multiple shelterbelts in Sahelian conditions and some simple agronomic measures

[submitted by C.J. Stigter, L.O.Z. Onyewotu and J.J. Owonubi, TTMI/AN Project, Forestry Research Institute of Nigeria and Ahmadu Bello University, Kano/Ibadan/Zaria, Nigeria]

Abstract

Without participation of farmers, extension personnel and local scientists and without establishing a pilot project, the Nigerian government established large areas of multiple shelterbelts of *Eucalyptus camaldulensis* that controlled desertification well. Agrometeorological research showed that this unprepared introduction led to an inefficient system of belts. The research showed that different belt direction, much shorter distances between belts, less depth of the belts, pruning of tree roots and branches at the tree/crop interfaces, a scientific determination of planting dates, improved use of manure and participative management of belts and crops would have improved the system and its yields. Such measures, combined with the alternative choice for dense agroforestry parkland or for a combination of belts and scattered trees would have made the systems acceptable to farmers if they had been involved in the details of such choices.

Background of service or success story

This work was carried out between 1989 and 1996 at the Yambawa shelterbelts, north of Kano, not far from the borders with Niger. The objectives were to assist farmers in returning to production on sandy soils reclaimed and protected from wind driven desertification by establishing multiple shelterbelts. The belts had already shown to be successful in settling wind blown sand directly and through enabling the return of grasses to the area.

The agrometeorological research showed that the consequences of wind behaviour between the shelterbelts extended for desiccating winds the theoretical review work of McNaughton developed for mechanical wind damage. Worsened because of a design error with respect to belt direction in relation to wind direction, the leewards protected area, in which high millet yields could be obtained after the application of tree root pruning, appeared not much more than five times the height of the belts. This quiet zone of about 60m was followed by a wake zone with increased turbulence, that even visually damaged a small crop area and returned yields to the much lower values obtained in conditions unprotected by the belts. A small windward protected area also existed.

These yield patterns could already be understood from early soil moisture patterns in bare soil that themselves can be explained from air movements between the belts. Between wider belts (240 m apart), pre-sowing soil moisture was still high at five times the height of the belt but had returned till values comparable to unprotected soil at 7.5 H. Comparable to the yields this was already the case for measurements at only 6 H between closer spaced belts (115 m) the previous year. The air movement distribution determining the gradients of transfer of water from the soil also determined gradients in the evapotranspiration from the crop, which suffered from the desiccating winds where also the soil water transfer was high and the pre-planting storage was least.

Economic benefits of service and/or policy matters served

Improved design rules propose that distances between belts perpendicular to the prevailing wind direction in the growing season should be less than 100 m, while they were between 115 and 300 m. The width of the belts could be halved (15 m instead of 30 m). It should
be considered as an alternative to plant scattered trees between the present belts. It is also likely that increasing the tree density in the indigenous parkland agroforestry systems still existing is a better solution than using belts.

Farmers should be allowed to prune not only the roots, but also the branches, diminishing the shade on adjacent intercrops. Economically yielding trees should be used. Farmers should have been involved in the choices of trees, crops and other aspects of the farming system, in a participative approach.

Another aspect was the choice of planting date. Involving the farmers in the research of reintroducing millet after root pruning of the trees, the researchers and the farmers each managed plots for which the sowing date was (i) traditionally determined, using a method based on the Ramadan, and (ii) determined scientifically, using an improvement of Kowal's approach. Yield advantages of between 20 and 40% were obtained with scientific determination of the start of the growing season. Using a test for the occurrence of dry spells drastically reduced false starts, particularly when data were used for the ongoing season.

Finally, economic benefits may be expected from further increase of the use of organic manure above the maximum available to the farmers at present.

The unprepared introduction of the belts led to misconceptions by the farmers on the functioning, the benefits and the drawbacks of the belts. This in turn led to wrong decisions of resource use, that is of land and trees as well as inputs. An initial participative pilot project, including local extension agents, prepared and guided by well informed local scientists, where possible assisted by an international support component, would have prevented most of these drawbacks.

Other important issues

The TTMI-Project was in several cases called upon to find urgently required local solutions to problems caused by wind in Africa, using trees in an agroforestry setting. Simple wind and wind related measurements can be very helpful in designing optimal solutions to local problems caused by wind. It may also be observed that wind as a carrier, here of sand and heat is often equally important under these African conditions than wind as a carrier of momentum. The work presented above has also made clear that the protective function of trees will remain an essential part of many solutions of problems related to expansion of desertification.

The research incidentally delivered a very nice proof of the importance of the distribution of rainfall over the season versus the amount received within that season. In 1993 509 mm (about 200 mm less than the 1962-1988 average) was received well distributed over the season. This gave 40 to 60% more dry matter yield and 35 to 50% more grain yield than in 1994, when 817 mm was received, very close to the average of the 1962 - 1971 period, but with torrential rains close after the late start of the season.

Conclusion

The monoculture of multiple *Eucalyptus camaldulensis* shelterbelts introduced at Yanbawa village in Kano State, Nigeria, was successful as a strategy of controlling desertification. It restored soil and landscape stability and possibly a form of agricultural stability of the once desertified area. The trees effectively control wind erosion and they shelter field crops from hot wind. Their unprepared introduction, with a design that gave incomplete protection, has however had bad implications for resource use and personal welfare of the farmers that own the land on which the shelterbelts were established. The extension services could not give the farmers any guidance on the consequences of the shelterbelts for cropping conditions, while the farmers are not allowed to manage the belts. Therefore misconceptions on the functioning, the benefits and the drawbacks of the belts led to wrong decisions of resource use, that is of land and trees as well as inputs. Farmers should get proper information from the extension services and all should be well informed by scientists in a better prepared participative approach of agroforestry between the belts. Any such further introductions of shelterbelts or
improved parkland agroforestry should be prepared by teams of farmers, extension agents, government officials and researchers.

Literature


Resource persons

Dr. Lambert O.Z. Onyewotu, Head, Shelterbelt Research Station, Forestry Research Institute of Nigeria (FRIN), P.M.B. 3239 (Katsina Road, opposite Army Baracks), Kano, Nigeria. To be reached by e-mail and fax through Prof. Owonubi

Prof. Kees Stigter, Ph.D., TTMI-African Network and Asian Picnic Model Project Liaison Office, Department of Environmental Sciences, Wageningen University, Duivendaal 2, 6701 AP Wageningen, The Netherlands. Fax: 31 317 482811. E-mail: <kees.stigter@user.metair.wag-ur.nl>
Use and suitable designs of shelterbelts and scattered trees as well as grasses for protecting agricultural production and infrastructure from wind driven sand encroachment and expanding desertification.

[submitted by C.J. Stigter, Ahmed Eltayeb Mohammed and Nawal K. Nasr Al-amin, TTMI/AN Project, University of Gezira, Wad Medani, Sudan]

Abstract

In Sudan, problems of wind induced sand encroachment towards an irrigated area could for the time being be solved by a planted Eucalyptus microtheca shelterbelt. Also sand settlement in the source area by trees and grasses to combat expanding desertification was successfully researched. Both studies quantified interaction of wind with trees and sand settlement to prevent this way further sand encroachment towards areas in use for agricultural production. The oldest work was on the use and on improved designs of shelterbelts to catch sand within and in front of the belt vegetation. A recommended improved design is now widely used to protect endangered parts of the Gezira irrigation scheme. The later work, that was terminated only recently, dealt with the selection, establishment and suitability of trees and grasses for use in settling sand. This was done in the secondary source area of the moving sand originally studied near the endangered parts of the irrigation scheme. Recommendations on suitable species have been made.

Background of service or success story

The objectives of the first case study in Sudan (1986 - 1993) in the Traditional Techniques of Microcliamte Improvement (TTMI) Project at the University of Gezira, Wad Medani, were to understand the mechanism by which a Eucalyptus microtheca shelterbelt prevented moving sand to reach irrigation canals and crop land and to improve the design of such belts. Belt areas had been established as pilot project by Forestry authorities at the periphery of the Gezira scheme in Central Sudan, but the sand catching mechanisms were not understood in any detail. This demanded the quantification of air and sand movement at the windward side of the belt for the season in which the sand moved towards the belt. For comparison the wind was quantified also in some periods during the other annual season, in which this same side was in the lee of the belt and sand could move away from the belt, although unmodified wind speeds were generally lower. The sand caught by the belt was for the largest part now protected by that same belt. The result can be summarized in that a ridged dune was formed by sand partly moved by the wind into the vegetation of the belt and partly deposited in the area in front of the belt. This sand became immobilized. This was done in this pilot project over many kilometers. The front part of the Eucalyptus shelterbelt survived several meters of sand deposition.

In the second, even more recent Sudanese case study (1992 - 1999), it was quantified which of some selected indigenous species would be most suitable to settle sand in and around scattered bushes in far out parts of the secondary source area of the sand that was blown towards the belt. The objective of this case study in the second phase of the TTMI-Project was to study how the amount of sand blown from the source area could be diminished and in general how further desertification could be combated. After sand samples had determined that the sand came all the way from beyond the White Nile and passed it, the mechanism by which it did so was also speculated on. Wind measurements were done at several heights in front of, at the sides and behind such trees/bushes. Simultaneously the patterns of settled sand that resulted from the interaction of wind, sand and biomass of the trees/bushes were quantified by simple approximations. Wind flows were directly related to biomass density distributions. The latter determined much of the sand settlement patterns, while physical catching played a role when substantial biomass was found near to the ground.
Economic benefits of service and/or policy matters served

Our results and existing literature on air movement around shelterbelts were used to develop design rules for shelterbelts for sand encroachment protection. In these rules, composition and geometry of such belts were discussed as to length, width, height, permeability, direction, openings, and species (growth rate, life span, tolerance, canopy geometry and byproducts). It is important to note that in the establishment phase protective structures have to be provided to protect young seedlings. To encourage establishment of shelterbelts, its width should be limited to the essential width for sand protection. However, its length should always be longer than the length of the originally affected area because of the variation in wind direction and the continuing land degradation of the surroundings. It was estimated that our belt would have performed well if it had been only 25 - 30 m wide and staggered planting had been adopted, decreasing its permeability. High belts with low permeability will lead to most sand being deposited in front of the belt. For borders like that of the Gezira Scheme, the belts should follow strictly its border pattern, whatever the direction is, to ensure a more complete shelter. If belt widths are small, roads should cross through overlapping ends of belt parts.

Some of these recommendations were subsequently used in substantial belt extensions by the Forestry authorities in charge, which for the time being successfully protect endangered parts of the Gezira scheme.

The results of the second study indicated that only seedlings that can establish under lower irrigation frequency and with a certain tolerance for salt and sodicity can survive and be used for revegetation in the area. The most successful indigenous species for sand settlement under windy conditions were (i) Leptadenia pyrotechnica trees/bushes, that provide good protection against wind erosion and expansion of desertification and were found to establish well under the local conditions, (ii) Panicum turgidum grasses, particularly when found in associations caused by its dissociation, and (iii) Prosopis juliflora trees, that also protected the area well, but due to its aggressivity presently suffers from a government ban, that seems not justified in this and some other regions. In a more recent development, the very poor local population living at the periphery of the belts developed (iv) Acacia tortilis plantings that, with controlled animal browsing, now protect, again for the time being, parts of the original shelterbelts from wind driven sand by settling this sand with these plant-ings in parts of the secondary source area near to the belts.

Other important issues

Tree species for belts should also be selected for their rapid growth and for a long life span with provision of many coppices. This will increase the protective life of the belt and its direct economic value. Moreover, use of different copices may facilitate the adoption of a rotation scheme of tree felling by removing segments of the belt along its length, without seriously reducing its protective value. Dense shrubs in the front row(s) followed by tall strong trees form the best combination for windward wind reduction, and hence protection against moving sand. Adverse effects of tree competition with crops should be avoided, eventually by root pruning and pruning of heavily shading branches/shoots.

Shelterbelt trees as well as scattered trees may supply other economic benefits to local people, e.g. fuel wood, building poles and possibly animal fodder. However, this is a critical area where a balance between protection efficiency and management of belt byproducts should be adequately maintained. The primary role of protection should have priority but additional economic benefits should not be ignored in designs of belts or parkland (agroforestry) establishments.

The quantitative profile of sand deposition in front of and within our wide belt most closely resembled that reported for a dune near equilibrium created around a porous fence with a closed lower part and vertically increasing permeability. It may be concluded from this resemblance that the deposited sand is acting as a zero permeability wind break. Our deposition also resembled that of snow in a defoliated shelterbelt of ten rows of trees, of which the height decreased from...
the middle to the two sides and where the maximum deposition was very close to the windward edge. This confirms that increasing belt width and decreasing permeability shift the maximum deposition towards the windward edge.

**Conclusion**

The TTMI-Project was in several cases called upon to find urgently required local solutions to problems caused by wind in Africa, using trees in an agroforestry setting. Simple wind and wind related measurements can be very helpful in designing optimal solutions to local problems caused by wind. It may also be observed that wind as a carrier of sand or biomass, heat and water vapour is often equally important under these African conditions than wind as a carrier of momentum. The work presented above has also made clear that the protective function of trees will remain an essential part of many solutions of problems related to expansion of desertification.

**Literature**


**Resource persons**

Prof. Ahmed Eltayeb Mohammed, Ph.D., Deputy Vice-chancellor, University of Gezira, Department of Environmental Sciences and Natural Resources, Faculty of Agriculture, P.O. Box 20, Wad Medani, Sudan. Fax: 249 511 40466/43174

Prof. Kees Stigter, Ph.D., TTMI-African Network and Asian Picnic Model Project Liaison Office, Department of Environmental Sciences, Wageningen University, Duivendaal 2, 6701 AP Wageningen, The Netherlands. Fax: 31 317 482811. E-mail: <kees.stigter@user.metair.wag-ur.nl>
Mrs. Dr. Nawal K. Nasr Al-amin, Range Science Department, Sudan University of Science and Technology, P.O. Box 6164, 11113 Khartoum, Sudan. Fax: 249 11 774559. E-mail: nawalkn@yahoo.com
Improved underground grain storage microclimate in cracking clay extended safe storage time by designing shallow pits, using chaff linings and constructing wide surface caps

[submitted by C.J. Stigter and Ahmed el-Tayeb Abdalla, TTMI/AN Project, University of Gezira, Wad Medani, Sudan]

Abstract

Diminished food security due to increasing climate variability encouraged farmers in Central Sudan to experiment with possible improvements of their traditional underground storage pits for sorghum grain. Microclimate measurements of grain moisture contents, grain temperatures and pit air carbon dioxide contents in experimental pits made it possible to test and improve their designs. Farmer innovations of using pits of only 50 cm deep and applying chaff linings at bottom and sides of these shallow pits made safe storage possible during at least two consecutive bad rainy seasons. Wide above surface caps were a necessary condition added by the research experience.

Background of service or success story

Storage of sorghum grain in round underground pits in the Central Clay Planes of Sudan is a traditional way of keeping surplus of good seasons for use during the dry season and preferably longer. With increasing climate variability and diminishing seasonal rainfall, food security suffered over the most recent decades. Research over the past 50 years or so already indicated that this traditional method should not be abandoned because of the socio-economic importance of underground storage of sorghum for farmers of different economic classes. However, in other than not very abundantly available non-cracking clay soils, this storage method suffers from too fast moisture ingress in two ways. Water vapour diffuses from the soil into the hygroscopic grain and liquid water seeps into pits that have cracks in their walls. This limits the period of safe storage (below 13.5% grain moisture content), particularly as soon as the next rainy season has arrived. Grain starts to suffer from deterioration, particularly near the bottom and sides of the pits, which affects relatively more grain in smaller pits used by poorer families. The Traditional Techniques of Microclimate Improvement (TTMI) Project at the University of Gezira, Wad Medani, selected in 1992 storage improvement as one of its priority research undertakings.

Economic benefits of service and/or policy matters served

Beyond subsistence farming, sorghum grain storage pits are used as a banking alternative. Because most farmers do not own any assets, they have no access to credits form banks. Underground pits are therefore not only in use by smaller farmers. The Sudanese government, worried by the decreasing food security, encouraged the continuation of this method. Warehouse storage for longer periods is economically less attractive for several reasons, including a less favourable storage environment. The TTMI-Project, encouraging problem oriented research assisting local small farmers and tenants, surveyed the application of storage pits and the thinking, feelings, ideas and practices of farmers applying this traditional kind of storage.

From these surveys it appeared that important farmer experiments were underway here and there, with innovations obtained from many years of experience. Particularly wider shallower pits and the use of chaff linings were believed by some of these farmers to have kept the grain in good conditions, also after longer times of storage. This, however, needed scientific verification.
as well as quantification. The quantification was necessary to be able to follow grain moisture contents, grain temperatures, pit carbon dioxide contents and grain viability in time, as a function of pit design. It could help to assess the way moisture ingress spoiled grain conditions most, as well as to determine the amounts of chaff that were needed and to evaluate any other measures that could influence the grain storage, particularly with respect to above ground surface conditions and modifications.

These monitorings were a great difference with former mainly statistical work on grain conditions in modified underground storage. Also the attention for innovations by farmers is part of an extension approach that takes experience of farmers seriously and that couples the results back to these experiences on the spot. When stores were opened we always had farmers present to assess with us the grain conditions also their way. It was clear from the results that the shallow pits were always having grain of much better conditions and thus higher economic value. Chaff had to be used abundantly, because of the compression by the grain, and at the start this should at least be a layer of 25 cm. Not only water vapour diffusion but also ingress of liquid water towards the grain was this way greatly reduced.

Other important issues

Ingress of liquid water through cracks nevertheless remained an occasional threat causing limited grain damage. This could only be completely excluded when wide surface caps, of in the order of 50 cm height and a diameter of 1 m beyond and around the perimeter of the pits, were applied. The absence of any water in the pits is important to prevent moulds spoiling any grain with toxic aflatoxins. These were only found in grain that had been at nearly 20% moisture content for a long time, at the bottom in an unlined pit with a crack.

Long term underground storage diminishes grain viability and seeds to be used for sowing the next season should not or only shortly be stored this way. Better underground storage conditions of shallower pits reduced starch and sugar contents less than in grain in deeper pits. Protein contents were not influenced by storage conditions.

The rating of grain quality by farmers, at opening of the pits, was based on taste, smell and colour. Their qualitative results were completely in line with the monitoring results.

A comparison with soils with more sandy components showed the cracking clay soils to be superior. The higher temperatures in the pits, particularly in the first year of storage, reduced insect damage that was limited to the very top and the sides nearest to the surface.

Conclusion

The innovative attempt by farmers to minimize and delay moisture movement to grain in underground pits by using shallow wider pits and by lining the pit walls and bottom with chaff was shown by micrometeorological research to be very efficient. Also the research innovation of using high wider caps, to close the catchment area of the cracks reaching the pit walls, proved effective. The longer term underground storage of grain in such improved pits is a viable contribution to fight famine, to maintain food security and to have an alternative banking system in dryland farming areas.

Literature


Resource persons

Dr. Ahmed el-Tayeb Mohamed, Deputy Academic Dean, University of Gezira, Department of Environmental Sciences and Natural Resources, Faculty of Agriculture, P.O. Box 20, Wad Medani, Sudan. E-mail: draabdalla@yahoo.com

Prof. Kees Stigter, Ph.D., TTMI-African Network and Asian Picnic Model Project Liaison Office, Department of Environmental Sciences, Wageningen University, Duivendaal 2, 6701 AP Wageningen, The Netherlands. Fax: 31 317 482811. E-mail: kees.stigter@user.metair.wag-ur.nl
Annex 9

Testing alley cropping (contour hedgerows) in semi-arid areas on flat and sloping land: soil and water conservation, competition, yields and economic factors

[submitted by C.J. Stigter, D.N. Mungai, C.K. Ong, J.M. Kinama and S.B.B. Oteng’i, TTMI/AN Project, Department of Meteorology and Department of Geography, University of Nairobi, together with the International Centre for Research in Agro-Forestry (ICRAF) and the Kenyan Agricultural Research Institute (KARI), Nairobi/Machakos, Kenya]

Abstract

Alley cropping tested by Mungai et al. on flat land, with prunings incorporated into the soil and one in every four rows of maize replaced by trees in the agroforestry plots, showed already in the late eighties/early nineties that alley cropping was unsuitable for flat semi-arid areas, because of its high risks for the farmers. This was mainly due to poor crop yields caused by (i) low biomass production of the trees under the low rainfall conditions in semi-arid areas, not sufficiently improving soil fertility and other soil conditions, (ii) higher than foreseen competition between trees and crops for water and nutrients, because of more overlap of root zones than expected, also away from the trees and also at lower horizons. The work of Kinama et al. in the nineties proved that on sloping land (in our case ca. 15%), contour hedge rows and mulch on the surface, for a comparable tree system added to maize or cowpea crops, considerably reduced soil loss and to a lesser extent water runoff. It, however, also reduced crop yields considerably, for the same reasons as in alley cropping on flat land. Nevertheless, strong trade-offs between the erosion control and crop productivity need not be a major deterrent to adoption by farmers, provided the trees have direct and significant benefits to farmers such as producing fodder or tree products that can be well marketed.

Background of service or success story

The testing of alley cropping and contour hedgerows in semi-arid areas was in the early- and mid-eighties advised by ICRAF to be done on-station instead of on-farm, because it was considered to represent a high risk and least-known option for farmers. Ever since the late eighties and early nineties it is clear that adoption by farmers is much lower than expected and our early work made clear why farmers have such negative feelings on alley cropping. Low biomass production, insufficiently improving soil conditions, and high competition for resources between trees and crops are the main causes.

A big advantage of the approach by Mungai et al. was the for agroforestry research unusual rigour of our agrometeorological quantification. This applied to radiation, in the form of shade quantification and understanding of competition for radiation, of soil temperature (also as an indicator of shade), of soil moisture and of root length density, both particularly important as indicators of time and place of actual competition. We also additionally measured, for limited periods, rates of photosynthesis and transpiration rates.

A most successful innovation was the use of soil temperature for following slow moving shading patterns by Mungai et al.. Successful tracing of measuring errors did take place in their investigation of the influence of the direction of mounting for solar tubes, integrating solar radiation interception. The use by Mungai et al. of simple equipment for measuring soil moisture showed the potential and the limitations of such multi-point measuring methods.

Kinama et al. were particularly successful in confirming through thorough quantification the large role that soil evaporation plays, also under semi-arid conditions and even under light mulch. They also skillfully combined the use of a neutron probe for deeper layers with time domain reflectometry for soil moisture in the surface layer. The quantification of the much higher influence of contour hedgerows on soil loss than on water conservation on sloping land, also
using quantitatively rainfall intensity in heavy showers, is again one of our successes due to emphasis on quantitative agrometeorological research in agroforestry.

**Economic benefits of service and/or policy matters served**

Our early work on flat land, confirmed by the later work on sloping land, showed/confirmed very clearly that agroforestry systems must at least provide strong physical protection of crops and/or soils and/or have a strong economic incentive to be of more interest to farmers. However, soil and water conservation have now generally been recognized as one of the main clear benefits of hedgerows on sloping land with an acceptable level of fertility.

In replacement agroforestry as well as in additive agroforestry there is more difference between yields in agroforestry systems and the controls at higher amounts of rainfall and with better rainfall distributions. However, our work also proves/confirms that it is difficult to increase crop yields considerably by alley cropping in the semi-arid tropics. The competitive effects of hedgerows on crops generally exceed the benefits gained by preventing the often small and only infrequently serious amounts of runoff commonly found in semi-arid tropics.

There has been a belief that trees and crops take their resources from different soil horizons, but it appears that there remains a lot of root overlap in many zones, making the existing competition understandable. In our research with *Cassia (Senna) siamea* trees, competition was stronger in the middle of the rows compared to closer to the trees. This could only be understood from higher overlap of roots in those areas, which we proved to exist from laborious quantification of root length densities.

**Other important issues**

The age of the agroforestry system also plays a role in these matters of competition, but influenced by the pruning regime applied to obtain the mulch for incorporation into the soil or distribution over the soil. In alley cropping in semi-arid areas root pruning cannot be exercised because this would limit even more the biomass production necessary for obtaining the mulch to be applied. In intercropping with hedges and scattered trees as well as with shelterbelts, tree root pruning successfully limits the competition of the trees with adjacent crops, particularly when the trees get older. However, tree growth is influenced by root pruning, depending on the pruning system applied and the rootning patterns of trees, as for example shown by Oteng'i et al..

The influence of trees on microclimate, particularly radiation and wind, so also soil and air temperature microclimate, heavily depends on heights and distribution patterns of the trees. In our alley cropping examples dealing with here, the trees remained low, bush like, and their influence on radiation, wind and temperature in the rows where the crops were grown remained quite limited to the tree/crop interface and the earlier growth stages. In fact below soil conditions were influenced most by the presence of the alley trees. As soon as we work with hedges, shelterbelts and/or scattered trees of sufficient height to considerably influence the wind regime, also the other microclimatic factors are more seriously influenced, as for example shown by Oteng'i et al.. This includes rainfall redistribution after interception by the trees.

The rainfall amounts above which the alley plots outyield the control plots depend on (i) whether we have replacement or additional agroforestry, (ii) the distance between the tree rows, (iii) the age of the agroforestry system and (iv) the rainfall distribution. Mungai et al. as well as later on Kinama et al. nevertheless demonstrated the existence of such a trend of having a “point” (a region of the rainfall scale) below which the control plots are yielding more than the alley plots but above which the opposite is true.

The use of additional amounts of artificial fertilizers reduces the competition between the trees and the crops. However, most farmers interested in alley cropping cannot economically afford such additions. This is why on sloping lands the most successful application of hedgerow
intercropping is limited to land with relatively fertile topsoil, which sustainability is then improved by the protection against loss of good soil. On degraded soils the amounts of mulch must be high or artificial fertilizers have to be added.

Other factors that have to be taken into account in introducing (contour) hedgerow intercropping are high and inflexible labour requirements (for pruning), secure long-term access to land, gender issues limiting access to land and rights to grow trees for women as well as compatibility of trees and crops and the economy of tree products.

**Conclusion**

The TTMI-Project was among the very first to jointly with ICRAF demonstrate that alley cropping on flat land was in most cases an unsuitable agroforestry system for semi-arid areas, because of its high risks for the farmers. In contour hedgerow intercropping such agroforestry systems must at least provide strong physical protection of crops and/or soils and/or have a strong economic incentive to be of more interest to farmers. However, soil and water conservation have now generally been recognized as one of the main clear benefits of hedgerows on sloping land with an acceptable level of fertility. The soil conservation appears of most importance. Our rigorous quantitative approach made it possible to determine well advantages and disadvantages of these agroforestry systems. For a full understanding of farmer adoption or the lack of it, a range of other factors have to be considered.

**Literature**


D.N. Mungai, 1995. A microclimatological approach on understanding maize yield performance in alley cropping in the semi-arid areas of Machakos District, Kenya. In: C.J. Stigter, F.J. Wang’ati, J.K. Ng’ang’a and D.N. Mungai (Eds.), The TTMI-project and the "Picnic"-model: an internal evaluation of approaches and results and of prospects for TTMI-Units, Wageningen Agricultural University, 111 - 123.


Resource persons

Prof. David N. Mungai, Ph.D., Department of Geography, University of Nairobi, P.O. Box 30197, Nairobi, Kenya. Fax: 254 2 336885 or 254 2 524001. E-mail: <D.Mungai@cgiar.org>

Prof. Kees Stigter, Ph.D., TTMI-African Network and Asian Picnic Model Project Liaison Office, Department of Environmental Sciences, Wageningen University, Duivendaal 2, 6701 AP Wageningen, The Netherlands. Fax: 31 317 482811. E-mail: <kees.stigter@user.metair.wag-ur.nl>

Prof. Chin K. Ong, Ph.D., International Centre for Research in Agro-Forestry (ICRAF), P.O. Box 30677, Nairobi, Kenya. Fax: 254 2 524001. E-mail: <C.Ong@cgiar.org>

Dr. Josiah M. Kinama, Kenyan Agricultural Research Institute (KARI), P.O. Box 340, Machakos, Kenya [Private: Box 00506 - 4934, Nairobi, Kenya]. E-mail: ["KARI-NARL"<soil@skyweb.co.ke>]

Dr. Silvery B.B. Oteng'i, Department of Meteorology, University of Nairobi, P.O. Box 30197, Nairobi, Kenya. E-mail: S0tengi@uonbi.ac.ke
Annex 10

Water waste in traditional and more recently developed on-farm irrigation management
in the Gezira Scheme in Central Sudan

[submitted by C.J. Stigter, Ahmed A. Ibrahim and Hussein S. Adam, TTMI/AN Project,
Department of Environmental Sciences and Natural Resources, University of Gezira,
Hydraulic Research Station, Ministry of Irrigation and Institute of Water Management and
Irrigation, University of Gezira, Wad Medani, Sudan]

Abstract

In the Gezira irrigation scheme in Central Sudan, serious symptoms of water waste have been identified in the last two decades, especially in sorghum and groundnut fields. To quantify losses, water use efficiencies and related parameters were obtained for these two food crops under the traditional attended daytime water application and the newly evolved unattended continuous watering method. The study has revealed wastage of irrigation water in both irrigation methods but at different rates and also differently for each crop. Higher wastes were observed in the groundnut sub-fields, which crop also suffers from excess water, and for the drier of the two years as well as in the unattended fields. A first approximation could be given, still including readily available water at harvest, of minimum water requirements in attended watering for maximum yields. In the drier year, when more irrigation water was applied, an amount equal to 30 to 50% of these minimum water requirements was lost in evaporation from standing water/wet surface, which is the main unproductive water. More frequent land levelling, aiming at minimum standing water in better attended irrigation and at better farm management (e.g. weeding) are priority measures proposed.

Background of service or success story

From results of a questionnaire prior to our field work, it followed that the tenant farmers in the Gezira scheme evolved their present unattended watering practices of groundnuts and sorghum out of the sheer necessity of engaging sharecroppers who themselves have to leave irrigation unattended because of their own need for additional off-farm employment/income. Also the serious fluctuations of water in the Minor canals, which should basically be used as storage reservoirs for the night, tended to bring farmers to use of water during the night for their private crops, defying the regulations of the strict night storage method which allows for day time attended watering only.

Tenants are dissatisfied with overall maintenance of the scheme. Authorities (Ministry of Irrigation, Sudan Gezira Board) are dissatisfied with tenants’ water use. These authorities are of the opinion that the farmers are wasting water by the unattended continuous (day and night) irrigation method they have evolved, especially for their private crops dura (sorghum) and groundnuts. There is the belief that remarkable savings in water would be obtained if the tenants would go back to the traditional night storage system, in which rather laborious and well-attended daytime application of water is practised.

The importance of preventing waste of water may be stressed by noting that Sudan is approaching the limit of depleting its quota of Nile water as determined under the agreements with Egypt. The 0.9 million hectares of the Gezira cum Managil irrigation scheme consumes about one third of these quota. In the context of this work, the late M.F. Sadek et al. determined that the present evaporation losses of Lake Nasser, the reservoir of the High Aswan Dam, in Egypt, is very likely close to 20% less than presently assumed. This shows the necessity of thorough quantification of all factors involved.

To possibly strengthen but at least verify the arguments of those who want to change the situation, it was thought useful to accurately quantify the problems under participatory on-farm
conditions. Quantitative agrometeorology has sufficiently strong methods to be able to do so. In this on-farm research, the most rigorously sampled neutron scattering method was used to determine the actual soil water deficits of the two crops. A simple Penman equation was used for approximating reference crop evapotranspiration and evaporation losses from standing water and wet soil surface. An updated approach using the Penman-Monteith equation was additionally applied. The shaded Piche evaporimeter was used to simplify the obtainment of the aerodynamic term of the Penman equation after local calibration for different seasons and a physical study of the shaded Piche to guarantee an appropriate performance. The most difficult quantification was that of the flows in the field channels (Abu Sittas) by a Vane Flow Meter in concrete tubes as flow guides, which quantified the irrigations on-farm.

**Economic benefits of service and/or policy matters served**

The replies to the questions posed to farmers on water management revealed that at present: (i) the tenants/farmers do not see any sense in attended watering after the first two irrigations; (ii) they normally adjust the openings of their field and feeder channels, so the flow of water, according to the area to be irrigated and their expected time of absence; (iii) this way they relieve themselves from the closely attended watering practice, which was observed to take about 18 to 24 full working hours per irrigation with normal flows (>> 5,000 m$^3$/day per feeder channel); (iv) many farmers admit the importance of adopting the Night Storage system but they apply the continuous flow method; (v) farmers appear not to understand that most of the standing water evaporates without being used by the crop; (vi) sharecroppers, who are originally from the western states of the Sudan, Chad or Central Africa, lack knowledge in irrigation but all tenants use sharecroppers in groundnut and sorghum, for several reasons.

Sharecroppers prefer to adopt continuous unattended free application of water, because for the private crops dura and groundnut opening of Field Outlet Pipes (FOPs) is uncontrolled by the authorities and they can make use of the irrigation time to work as hired labour in fields of other crops. The above strongly links the necessities of sharecropping and the unattended watering to socio-economic backgrounds. This weakens the assumption that the unattended watering practice is a mere water availability problem.

The study has revealed wastage of irrigation water in both irrigation methods but at different rates and also differently for each crop. In the attended fields, the average seasonal over-irrigation, which is the difference between average application depth Q and average soil moisture deficit SWD, was observed to range between 0.4 and 1.5 of SWD (0.3 and 0.6 of Q) and the corresponding values in the unattended field were 0.6 and 3.2 of SWD (0.4 and 0.8 of Q). The farm water application efficiency values were 50% of those shown in the literature and this also indicates that much of the water application in the Gezira is not being economically invested, due to lack of other inputs, mainly nutrients.

It was calculated that 570 mm was likely to be a good first approximation of the minimum requirements for groundnut in the Gezira farming system under attended irrigation. Higher water applications reduce groundnut yields. For the two sorghum varieties, Fitareeta and Hageen, of which the latter needs one irrigation more, these values appear 470 and 560 mm respectively. These values are for the present field topography and other farm management conditions. These values also still include a too high soil moisture value at maturity, which was estimated as 50 to 80 mm readily available water in this case. Because no surface runoff occurs from the fields, the Gezira free surface evaporation losses, which for the drier year amounted to the highest values (170 mm - 230 mm) for groundnut in the attended and the unattended fields respectively, that are 30 to 50% of the above minimum requirements of the two crops, will remain the main type of non-productive water reaching the present fields. These values were 180 mm - 200 mm for dura in that same year and 70 mm - 130 mm (again attended versus unattended for groundnut) and 70 mm - 80 mm for the wetter year of data taking.

The results confirm that irrigation water is wasted in both application methods, but at different rates and differently for each crop. The waste was higher in unattended irrigation of
both dura and groundnut, and the waste was larger on groundnuts. It had also larger consequences because groundnut yields drop with excess water applied. Even much of the consumptive use is economically ill invested in non fertilized dura, because with higher inputs the same amounts of water would give higher returns. The application differences were mainly due to the watering methods, causing different amounts of standing water, and the methods of determining the moment of irrigation. Another type of non-productive water is the readily available water retained in the soil profile at the end of each growing season.

More efficient water and farm management (e.g. weeding) in the scheme is crucial for obtaining the same or somewhat higher yields with other external inputs remaining at the present low level. The most important measure in this respect would be to adopt a land levelling program to the practical limits possible and to apply partly or fully attended watering on small areas, as was recommended in the traditional night storage system. Minimum practical standing water in the furrows during and immediately after each irrigation must be targeted. Economic measures related to the payment and prize of irrigation water should also be taken.

These quantitative on-farm water waste determinations belong to the innovative results of this research. Knowing now much more precisely how large the problem is and which components it quantitatively has will contribute much to the arguments of those who want to take the proposed measures.

**Other important issues**

The main points that should be used in a dialogue between authorities and tenants on the necessary adaptation of present watering methods are that:

1. irrigation water is limited at local and national levels, yet the present irrigation practices are inefficient. However, only when clear profits or other incentives convince the farmers, water may be more wisely used on-farm. Less waste will help to do away with overindenting and to maintain uninterruptedly the required commands in the Minor canals, which reduces the total seasonal irrigation time by increasing FOP discharges where they are too low and will help to solve the tail end problems;

2. if the case study reported on is indeed representative, in the order of at least 20-40% on-farm saving in irrigation water will be obtained if more efficient on-farm application methods such as attended daytime irrigation are adopted in the scheme, while minimizing the last irrigation may also contribute;

3. poor on-farm water management can be attributed to (i) the large sizes of land being irrigated at a time in unattended watering when the NS system is not applied, (ii) the lack of attention for the duration of the within field water flows and (iii) the visual method the farmers use for their irrigation satisfaction. At the highest places of the field parts considered for irrigation at the same time, minimum depths of water are to be used in the furrows, while standing water by the end of the irrigation should be avoided as far as possible; this means separate irrigation of different levels in the field for appropriate periods as done in the traditional attended irrigation method. Otherwise occasional precise land levelling is recommended; and

4. when dealing with a sharecropper, the tenant should be sure that his partner is attending the irrigations and is provided with the means to do so. This leads to lowest possible water costs.

**Conclusions**

Results as obtained in this case study will convince authorities to set up larger scale validations and to carry out improvements, e.g. in levelling and maintenance, to decrease impact
of factors that influence water use efficiency negatively and to satisfy tenants. In Sudan this may best be set up through farmers’ unions and production councils. Future research should improve knowledge on crop water requirements at different crop stages and demonstrate substantial profits from diminishing water use. As long as individual tenants are not yet charged for their actual water use, water waste should be seriously discouraged by allocating quota of water.

**Literature**


A.A. Ibrahim, 1995. Water use and water waste under traditional and non-traditional irrigation practices in the Gezira Scheme, Sudan. In: C.J. Stigter, F.J. Wang'ati, J.K. Ng'ang’a and D.N. Mungai (Eds.), The TTMI-project and the “Picnic”-model: an internal evaluation of approaches and results and of prospects for TTMI-Units, Wageningen Agricultural University, 165 - 172.


**Resource persons**

Dr. Ahmed A. Ibrahim (dit Kabo), Hydraulics Research Station (HRS), P.O. Box 318, Wad Medani, Sudan. Fax: 249 511 42265. E-mail: <hrs_sudan@hotmail.com>

Prof. Hussein S. Adam, Ph.D., Institute for Water Management and Irrigation, University of Gezira, P.O. Box 719, Wad Medani, Sudan. Fax: 249 511 43174. E-mail: <hsadam2002@yahoo.com>
Annex 11

The U.S. Drought Monitor

Donald A. Wilhite and Mark D. Svoboda

Abstract

The development of an effective drought monitoring system presents some unique challenges because of the slow onset nature of this natural hazard. Drought impacts are largely non-structural and regional in scale, making both assessment and response difficult. The different types of drought further complicate monitoring and impact assessment efforts. In 1999, an experimental drought assessment product, the U.S. Drought Monitor, was developed in the United States through a partnership between the National Drought Mitigation Center at the University of Nebraska, the U.S. Department of Agriculture, and the National Oceanic and Atmospheric Administration. Because of severe and widespread drought conditions in the United States at the time, this product became operational within a few months. The U.S. Drought Monitor is a weekly map that represents a snapshot of drought conditions. Authors of the product incorporate multiple climate indices and indicators in determining drought severity classes. A network of climatologists, hydrologists, and others at the state and regional scale are provided the opportunity to comment on drafts of the map before it is released to the public at the same time each week via the Internet. A scheduled map release time best meets the needs of the diverse user audience. In the past three years this product has become widely accepted by the scientific and policy communities, the private sector, and the media. More that 1.2 million hits on this map were recorded during 2001. In addition to users that directly access the web site, the map also appears in many local, regional, and national newspapers and on many television stations.

Background

Monitoring drought presents some unique challenges because of its distinctive characteristics (Wilhite, 2000a). First, drought is a slow-onset, creeping phenomenon, which makes its onset and end difficult to determine. The effects of drought accumulate slowly over a considerable period of time and may linger for years after the termination of the event. Second, there is no universal or widely accepted definition of drought. This adds to the confusion about whether or not a drought is occurring and its severity. Third, several types of drought exist, and the factors or parameters that define it will differ from one type to another. For example, meteorological drought is principally defined by a deficiency of precipitation from expected or “normal” over an extended period of time, while agricultural drought is best characterized by deficiencies in soil moisture. This parameter is a critical factor in defining crop production potential. Hydrological drought, on the other hand, is best defined by deficiencies in surface and subsurface water supplies (i.e., reservoir and ground water levels, streamflow, and snowpack). These types of drought may coexist or may occur separately. Fourth, drought impacts are nonstructural and spread over a larger geographical area than damages from other natural hazards. This characteristic complicates both assessment and response efforts. Each of these challenges has hindered accurate, reliable, and timely monitoring of drought; estimates of severity and impacts; and the formulation of drought preparedness plans.

Drought episodes differ in terms of their intensity, duration, and spatial extent. All types of drought originate from a deficiency of precipitation, but the nature of the impacts associated with these extended periods of precipitation deficiencies changes dramatically as the event continues over several seasons or years. Like earthquakes, droughts have an epicenter, but

---

1 Donald A. Wilhite and Mark D. Svoboda are director and climatologist, respectively, at the National Drought Mitigation Center, University of Nebraska, Lincoln, Nebraska 68583 U.S.A.
because of the slow-onset nature of drought and its extended duration, the area of maximum intensity will likely change with time, shifting from one region to another and expanding and contracting in spatial extent. In the early stages of drought, impacts may be confined to rain-fed agriculture. As drought persists, surface and subsurface water supplies and, therefore, a wider range of users, will be affected. Water in hydrological storage systems is often used for multiple and competing purposes such as irrigated agriculture, drinking water, power generation, flood control, and recreation. Surface and subsurface water supplies are also slow to recover when precipitation returns to normal, extending impacts for additional months or years. Competition for water in hydrological storage systems escalates during drought, increasing conflicts between water users. A successful drought monitoring system must integrate data and information from multiple sources (i.e., government agencies) and include multiple parameters to capture the true intensity and severity of the event and its far-reaching impacts. The U.S. Drought Monitor has been able to successfully address many of these unique drought characteristics and monitoring challenges.

Several other factors also explain the ineffectiveness of drought monitoring systems. These factors are more directly associated with inadequacies in the systems themselves. First, monitoring systems have often been dependent on an inadequate network of weather stations. These data are often reported infrequently (i.e., monthly) so that information is not readily available to decision makers at critical times or decision points. Second, drought monitoring systems are often based on a single parameter or index. Because of drought’s complexities, no single parameter or index can adequately capture the intensity and severity of drought and its potential impacts on a diverse group of users. Each index has both its strengths and weaknesses, and these often vary spatially. Third, the delivery of information products to assess drought severity is often untimely. Distribution of information to users has often been by mail; it is out of date by the time it reaches users, decreasing its value significantly. Fourth, information products are often developed without a clear understanding of user needs, or users are confused about how to apply this information when making critical climate-based decisions. The result is that the products are often underused.

Globally, emphasis on drought preparedness planning has increased significantly in recent years as a means of helping countries and regions improve drought coping capacity (Wilhite, 2000b). Monitoring, early warning, and prediction are key ingredients of a drought preparedness plan (Wilhite, Sivakumar, and Wood, 2000). The other key ingredients are risk and impact assessment and mitigation and response (Wilhite et al., 2000). Monitoring and early warning systems are critical because they continuously track key drought indicators (e.g., precipitation, soil moisture, streamflow, reservoir and ground water levels) and a range of climate-based indices. These tools allow for early detection of drought conditions and the more timely triggering of mitigation and emergency response measures. The Drought Monitor has already become an essential component of the United States’ initiative toward a national drought policy (Wilhite, 2001).

Description: Evolution of the U.S. Drought Monitor

There has been no comprehensive, integrated drought monitoring system in the United States (Svoboda, 2000). In the past decade or so, severe droughts have been widespread in their occurrence and have affected most of the country. Many regions have been affected over several consecutive years and on more than one occasion. Drought is more commonly associated with the western United States since much of this region is typically arid to semi-arid. This region experienced widespread drought conditions from the late 1980s through the early 1990s. The recurrence of drought in the mid 1990s through 2001 has continued to emphasize the need for improved drought monitoring in this region. For the more humid eastern United States, drought has also been a common visitor in recent years. Most of the eastern United States experienced an extremely severe drought in 1998-99, and in parts of the southeast drought continued to occur each year, especially in Florida and Georgia, through 2001.
These drought events highlighted the deficiencies of U.S. drought monitoring efforts and stressed the importance of developing a more coordinated approach that would make optimum use of the Internet for data sharing and analysis, communication, and product delivery. As is the case in most countries, climate and water supply monitoring in the United States is fragmented at the national and state level. Improvements in drought monitoring must bring together the resources available in federal and state agencies, universities, and other groups. The U.S. Drought Monitor map is an example of a product that successfully integrates information from multiple parameters and sources to assess the severity and spatial extent of drought in the United States on a weekly basis. This map product has been widely accepted and is used by a diverse set of users to track drought conditions across the country.

Since the creation of the National Drought Mitigation Center (NDMC) in 1995, we have been discussing how this country could do a better job of tracking and assessing the severity of droughts. One question we often hear is “How does this drought compare, or rank, with other droughts or the drought of record for this region or state?” Or “Just how severe is this drought?” These kinds of questions are often difficult to answer, and for people lacking training in climatology, those answers are often difficult to comprehend. We need to understand the intensity, duration, and spatial extent of historical and current droughts and their economic, social, and environmental impacts. This information (i.e., drought climatology) gives states and communities, for example, critical information that can be incorporated in drought preparedness plans that are directed at reducing risks associated with future droughts.

Until recently, there was no comprehensive nationwide effort to consolidate or centralize drought monitoring activities being conducted by or between various federal, state, or regional entities. In 1998, discussion began between the NDMC and meteorologists at the National Centers for Environmental Prediction/Climate Prediction Center (NCEP/CPC) of the National Oceanic and Atmospheric Administration (NOAA) on the development of a classification system for droughts, in much the same way the Fujita Tornado Intensity Scale (F0-F5) categorizes tornadoes and the Saffir-Simpson Hurricane System (Category 1-5) rates hurricane strength. From these discussions emerged a drought classification scheme that ranges from D1 to D4 (moderate, severe, extreme, and exceptional). In 1999, these discussions continued and were expanded to include scientists at the U.S. Department of Agriculture’s Joint Agricultural Weather Facility (USDA/JAWF). The purpose of these discussions was to create a partnership to develop and implement an integrated drought monitoring system and a suite of products available via the World Wide Web. The National Drought Policy Act, passed by the U.S. Congress in the summer of 1998, and the subsequent formation of the National Drought Policy Commission (NDPC) and its working groups in 1999 provided additional momentum to improve drought monitoring efforts in the United States. A working group on monitoring and prediction formed by the NDPC during the spring of 1999 provided additional opportunities for interactions with a larger group of climatologists throughout the country on drought monitoring issues and helped to form the template for early versions of the drought monitor map, first released on an experimental basis on May 20, 1999, as a bi-weekly product. Comments on this experimental product were solicited from field offices of the National Weather Service, NOAA’s Regional Climate Centers, and others.

The Drought Monitor continued to be produced on an experimental basis until August 1999. The drought in the Northeast and mid-Atlantic region during summer 1999 also provided additional recognition and application for the map. The Drought Monitor became an operational product in August 1999 when it was officially released at a joint White House press conference conducted by the Departments of Commerce and Agriculture. The Drought Monitor had gone from an experimental bi-weekly map to a full-fledged weekly operational product in a few months. The Drought Monitor is maintained on the web site of the National Drought Mitigation Center at the University of Nebraska-Lincoln (http://drought.unl.edu/monitor/monitor.html).
The Drought Monitor

The Drought Monitor map represents a snapshot of current drought conditions; it is not a forecast. This assessment includes the 50 U.S. states, Pacific possessions, and Puerto Rico. The product consists of a color map, showing which parts of the United States are suffering from various degrees of drought, and accompanying text. The text describes the drought’s current impacts, future threats, and prospects for improvement. The Drought Monitor is a synthesis of several different climate indices and parameters and is by far the most user-friendly national drought monitoring product currently available in the United States. It is particularly well suited for use by mainstream media because it represents state-of-the-art scientific expertise and is packaged as a timely, colorful, unambiguous map. Currently, the World Wide Web is the primary distribution vehicle. NOAA also distributes the map through some internal channels. The obvious advantages of the Web are that there are no distribution costs and the information is instantly available and always current. The obvious disadvantage is that not everyone has access to the Web. However, the number of persons or organizations in the United States without web access, either direct or indirect, is quite small. Our focus to this point has been how to best disseminate the product in the most timely and cost-effective manner.

Because no single definition of drought is appropriate in all situations, water planners and others must rely on a variety of data or indices that are expressed in map or graphic form. The authors of the Drought Monitor rely on the input of several key indices and ancillary indicators from different agencies to create the final map, which is posted each Thursday morning. The six key parameters making up the current scheme are the Palmer Drought Index, Climate Prediction Center’s Soil Moisture Model (percentiles), USGS Daily Streamflow (percentiles), Percent of Normal Precipitation, Standardized Precipitation Index (SPI), and a remotely sensed Satellite Vegetation Health Index. The final color map summarizes all of this information in an easy-to-read format that shows where drought is emerging, lingering, and subsiding.

Creating the Drought Monitor

The idea is to classify droughts on a scale from zero to four (D0-D4), with zero indicating an abnormally dry area and four reflecting an exceptional drought event (i.e., 1 in 50 year event). The drought intensity categories are based on six key indicators and many supplementary indicators. The Drought Monitor summary map and narrative identify general drought areas, labeling droughts by intensity from least to most intense. D0 areas (abnormally dry) are heading into drought or recovering from drought, but still experiencing lingering impacts (i.e., conditions have not yet returned to normal).

The Drought Monitor also shows which sectors are presently experiencing the majority of impacts, using labels of A (agricultural crops, livestock, range or pasture), W (water supplies), or F (high risks of fire danger). For example, an area shaded and labeled as D2 (A) is in general experiencing severe drought conditions that are affecting the agricultural sector but at present are not affecting water supplies. The area is not seeing a heightened fire risk in association with this dryness. An area shaded and labeled as D2 with no A, W, or F would be experiencing impacts in all three sectors. In this way the map can make a distinction between areas that may be experiencing agricultural and hydrological drought and those areas that may be experiencing one or the other. The map authors are careful to not bring an area into or out of drought too quickly, recognizing the slow-onset characteristics of drought and the potential for lingering impacts.

Table 1 below illustrates the drought severity classification system that is currently used in the preparation of the map each week. This classification is not static; it continues to evolve as the authors gain more experience and new data sources and technologies become available.

Although the maps are based on many inputs, the final maps are tweaked to reflect real-world conditions as reported by numerous experts throughout the country. The map is a blend of objective analysis and subjective interpretation. The initial draft of the map is produced on Monday and distributed via e-mail to more than 125 climate, water supply, and agricultural...
specialists throughout the country. These persons are asked to review the map and provide comments to the author. These regional experts often have a better understanding of the local situation because of their direct contacts with water and natural resources managers. Based on comments from these reviewers, the map is revised and a second draft is distributed. The dialog between map authors and the reviewers is very instructive and often leads to extremely useful and interesting scientific debates. The final map is completed by Wednesday night and placed on the web site at 0730 each Thursday morning. Previous maps are archived, and users can also see an animation of the past 6- and 12-week periods to better visualize the changing spatial extent and severity of drought conditions across the country. The Drought Monitor map for January 29, 2002 (Figure 1) provides an example of this map product.

In addition to the Drought Monitor map, users can also look at a suite of products that went into the making of the maps for that week (Current Conditions section) as well as forecast products (Forecast section) available from the Climate Prediction Center/NOAA. This web site and the NDMC’s web site (http://drought.unl.edu) provide one-stop shopping for people interested in drought and water supply conditions, drought planning and mitigation, historical climatology, and drought risk assessment.

Benefits to User Community

As mentioned previously, user acceptance of the Drought Monitor has exceeded our greatest expectations. For example, during the summer of 2000, the Drought Monitor web site was receiving more than 30,000 hits/week; it received more than 1.75 million hits in all of 2000. If user numbers are extended to include those persons actually seeing the product, this number would be much greater since it is shown on many local television stations and national news broadcasts, including The Weather Channel, and in local, regional, and national newspapers. The media has been especially quick to pick up on and use the new product to inform their readers and listeners of the status of drought conditions. During 2001, total hits on the Drought Monitor were nearly 1.2 million with user accesses peaking during the summer months. May 2001 hits were nearly 450,000 and averaged about 350,000/month for the period from May through September.

In addition, the product has been widely used by agricultural producers, commodity brokers, water and natural resource managers, congressional delegations, and local, state, and federal agencies. States significantly affected by drought in 2000, for example, used the product to track the severity of drought conditions in their state and make policy decisions on emergency and mitigation actions. Users appreciate a product that simplifies a difficult and complex issue but is based on scientific climatic indices and parameters.

Certainly, the Drought Monitor cannot always capture the local situation accurately. The partners in this activity continue to seek better and more timely data products that will assist them in their weekly assessments. Users are also encouraged to use local and regional sources of information (i.e., state climate offices, regional climate centers) to obtain more detailed information. We continue to solicit greater input from the field to make sure that the product is representing what is occurring in the real world. The partners are also continuously seeking input from the user community. The NDMC organized a Drought Monitor Forum in November 2000 to assess the successes and shortcomings of the product. Many users attended this meeting and provided excellent comments to the authors of the weekly map. We are now incorporating a series of improvements into this product based on these discussions. Continuing to listen to our users while at the same time striving to improve the science of drought monitoring by improving networks and developing new climate indices and other assessment tools will make this a better product in the future. One way of ensuring that this will happen is to interface with users. A second drought monitor forum is scheduled for April 2002 to receive further feedback from the product’s diverse user group.
Conclusions

Drought differs from other natural hazards in several ways. These differences complicate drought monitoring and help explain the ineffectiveness of many monitoring systems. With greater emphasis on drought preparedness and the need to reduce the risks associated with future drought episodes, it is imperative that we improve drought monitoring capability. The U.S. Drought Monitor, developed in 1999 as an experimental product by the NDMC, USDA, and NOAA, has quickly become an operational product that has gained widespread acceptance by scientists, resource managers, policy makers, the businesses community, and others. The success of this product is largely the result of the collaboration between the principal partners and other organizations, the integration of several climate and water supply indices and other climate parameters into a weekly assessment of drought severity and spatial extent, the use of the Internet in both product development and dissemination, and the involvement of the user community. There is a strong commitment by the principal partners to work closely with the wide range of users throughout the country to continue to improve this product. The Drought Monitor map and the procedures used in its production are transferable to other drought-prone regions with appropriate modifications.

References


Resource persons
Dr. Donald A. Wilhite
Director,
National Drought Mitigation Centre
International Drought Information Centre
Professor, School of Natural Resource Sciences
239 L. W. Chase Hall
University of Nebraska
Lincoln, Nebraska 68583-0749
U. S. A.

phone: 402 472-4270
phone: 402 472-6707 (NDMC secretary)
fax: 402 472-6614
<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Possible Impacts</th>
<th>Palmer Drought Index</th>
<th>CPC Soil Moisture Model (Percentiles)</th>
<th>USGS Weekly Streamflow (Percentiles)</th>
<th>Percent of Normal Precipitation</th>
<th>Standardized Precipitation Index (SPI)</th>
<th>Satellite Vegetation Health Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>D0</td>
<td>Abnormally Dry</td>
<td>Going into drought: short-term dryness slowing planting, growth of crops or pastures; fire risk above average. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered</td>
<td>-1.0 to -1.9</td>
<td>21-30</td>
<td>21-30</td>
<td>&lt;75% for 3 months</td>
<td>-0.5 to -0.7</td>
<td>36-45</td>
</tr>
<tr>
<td>D1</td>
<td>Moderate Drought</td>
<td>Some damage to crops, pastures; fire risk high; streams, reservoirs, or wells low, some water shortages developing or imminent; voluntary water-use restrictions requested</td>
<td>-2.0 to -2.9</td>
<td>36483</td>
<td>36483</td>
<td>&lt;70% for 3 months</td>
<td>-0.8 to -1.2</td>
<td>26-35</td>
</tr>
<tr>
<td>D2</td>
<td>Severe Drought</td>
<td>Crop or pasture losses likely; fire risk very high; water shortages common; water restrictions imposed</td>
<td>-3.0 to -3.9</td>
<td>36438</td>
<td>36438</td>
<td>&lt;65% for 6 months</td>
<td>-1.3 to -1.5</td>
<td>16-25</td>
</tr>
<tr>
<td>D3</td>
<td>Extreme Drought</td>
<td>Major crop/pasture losses; extreme fire danger; widespread water shortages or restrictions</td>
<td>-4.0 to -4.9</td>
<td>37013</td>
<td>37013</td>
<td>&lt;60% for 6 months</td>
<td>-1.6 to -1.9</td>
<td>36325</td>
</tr>
<tr>
<td>D4</td>
<td>Exceptional Drought</td>
<td>Exceptional and widespread crop/pasture losses; exceptional fire risk; shortages of water in reservoirs, streams, and wells creating water emergencies</td>
<td>-5.0 or less</td>
<td>36922</td>
<td>36922</td>
<td>&lt;65% for 12 months</td>
<td>-2.0 or less</td>
<td>37011</td>
</tr>
</tbody>
</table>

Additional indices used, mainly during the growing season, include the USDA/NASS Topsoil Moisture, Crop Moisture Index (CMI), and Keetch Byram Drought Index (KBDI). Indices used primarily during the snow season and in the West include the River Basin Snow Water Content, River Basin Average Precipitation, and the Surface Water Supply Index (SWSI).
ABSTRACT

The Weekly Weather and Crop Bulletin (WWCB) provides an invaluable source of information pertinent to regional, national, and international agriculture. Since 1978, the WWCB has been produced by the Joint Agricultural Weather Facility (JAWF), a global agricultural weather and information center located within the United States Department of Agriculture (USDA) in Washington, D.C. The JAWF is jointly operated by the Department of Commerce’s Climate Prediction Center (DOC/CPC), and USDA’s World Agricultural Outlook Board (WAOB) and the National Agricultural Statistics Service (NASS). The publication is a shining example of how two major departments within the federal government can mutually cooperate, combining meteorology and agriculture to provide a service that benefits the economic well-being of the nation. The WWCB highlights weekly meteorological and agricultural developments on a national and international scale. Written summaries of weather and climate conditions affecting agriculture are provided, along with detailed charts and tables of agrometeorological information that are appropriate for the season.

AGROMETEOROLOGICAL SERVICE AND SUCCESS STORY

1. Background

The Weekly Weather and Crop Bulletin (WWCB) is deeply rooted in the past. First published in 1872 as the Weekly Weather Chronicle, the publication has evolved over the past 129 years into one that provides a vital source of information on weather, climate, and agricultural developments worldwide (Figure 1). A brief history of the WWCB can be found in Table 1. Although the major emphasis of the WWCB is on U.S. weather and its impacts on agricultural production, the publication took on an international scope in 1978, with the creation of the Joint Agricultural Weather Facility (JAWF). The JAWF is an operational unit, monitoring world-wide weather conditions and preparing real-time agricultural assessments (Puterbaugh, et al. 1997; Motha and Heddinghaus 1986). Information on U.S. agriculture is obtained for each state through a network of county extension agents, farmers, and volunteer crop reporters, and summarized at the NASS State Statistical Offices (SSOs). This information is then sent to NASS headquarters in Washington, D.C., and relayed to JAWF. Weather data and information for the United States and international areas are supplied by the National Weather Service (NWS). The international portion contains weather information from over 7,000 global observing stations obtained through the Global Telecommunications Network and managed by the World Meteorological Organization (WMO).

2. Regular Features in the WWCB

The WWCB contains observations of both physical and biological elements that are used to track the cumulative affects of weather on crop growth and development. Although the main emphasis of the WWCB is on current growing-season weather conditions and agricultural developments in the United States, summaries and charts for major international areas are included, as well as special articles and charts on episodic weather events. Table 2 lists the descriptive summaries, charts, and tabulations regularly published in the WWCB.

---

1Thomas L. Puterbaugh and Bradley R. Rippey, respectively, are Supervisory Meteorologist and Agricultural Meteorologist at the United States Department of Agriculture, World Agricultural Outlook Board, Washington D.C. 20250-3812, U.S.A.
Cold air stubbornly clung across the Southeast, resulting in another minor freeze on January 9 as far south as Florida's northern citrus areas. Weekly temperatures averaged as much as 10°F below normal in Florida. In addition, widespread rain and snow fell across the East early in the week and again at week's end, aiding pastures and winter grains in the southern Atlantic region, and providing some relief from long-term drought. Meanwhile, record warmth overspread the Plains and Midwest, boosting temperatures 6 to 20°F above normal. On January 8, several locations noted monthly record-high temperatures. Although the warm weather permitted off-Continued on page 5)
<table>
<thead>
<tr>
<th>Title</th>
<th>Dates</th>
<th>Managing Department</th>
<th>Bureau or Office</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekly Weather Chronicle</td>
<td>November 1872 - April 1881</td>
<td>War</td>
<td>Signal Corps</td>
<td>The Chronicle was a two-page release containing a general weather summary</td>
</tr>
<tr>
<td>Weather Crop Bulletin</td>
<td>May(?) 1888- June 1891</td>
<td>War</td>
<td>Signal Corps</td>
<td>The Bulletin was issued weekly during the growing season (May to Sept.) and monthly during the other months.</td>
</tr>
<tr>
<td>Weather Crop Bulletin</td>
<td>July 1891- January 1896</td>
<td>Agriculture</td>
<td>Weather Bureau</td>
<td>The Weather Service of the Signal Corps was transferred from the War Department to the Department of Agriculture (USDA) on Jul. 1, 1891, creating the Weather Bureau.</td>
</tr>
<tr>
<td>Climate and Crop Bulletin</td>
<td>February 1896- August 1904</td>
<td>Agriculture</td>
<td>Weather Bureau</td>
<td>Title change</td>
</tr>
<tr>
<td>Weather Crop Bulletin</td>
<td>August 1904- January 1906</td>
<td>Agriculture</td>
<td>Weather Bureau</td>
<td>Title change</td>
</tr>
<tr>
<td>National Weather Bulletin</td>
<td>February 1906- June 1914</td>
<td>Agriculture</td>
<td>Weather Bureau</td>
<td>Title change. The Snow and Ice Bulletin, which had been issued separately since 1894, was added during the winter from Dec. 1919 to Dec. 1921.</td>
</tr>
<tr>
<td>National Weather and Crop Bulletin</td>
<td>July 1914- December 1921</td>
<td>Agriculture</td>
<td>Weather Bureau</td>
<td>Title change. The Snow and Ice Bulletin, which had been issued separately since 1894, was added during the winter from Dec. 1919 to Dec. 1921.</td>
</tr>
<tr>
<td>Weather, Crops, and Markets</td>
<td>January 1922- December 1923</td>
<td>Agriculture</td>
<td>Weather Bureau</td>
<td>The publication was reduced in content, consolidated with Crops and Markets.</td>
</tr>
<tr>
<td>Weekly Weather and Crop Bulletin</td>
<td>January 1924- June 1940</td>
<td>Agriculture</td>
<td>Weather Bureau</td>
<td>The publications were again separated. The Bulletin had its final name change, acquired much of its present content.</td>
</tr>
<tr>
<td>Weekly Weather and Crop Bulletin</td>
<td>July 1940- July 1965</td>
<td>Commerce</td>
<td>Weather Bureau</td>
<td>The Weather Bureau was transferred from USDA to the Department of Commerce (DOC) on Jul. 1, 1940.</td>
</tr>
<tr>
<td>Weekly Weather and Crop Bulletin</td>
<td>July 1965- May 1979</td>
<td>Commerce</td>
<td>Environmental Data Service</td>
<td>On Jul. 13, 1965, the Environmental Science Service (ESSA) was created as an agency within DOC. The Environmental Data Service (EDS) was established in ESSA. On Oct. 3, 1970, EDS moved into the newly created National Oceanic and Atmospheric Administration, and the Weather Bureau became the National Weather Service (NWS).</td>
</tr>
</tbody>
</table>
The Climate Analysis Center (CAC) was established within the NWS in May 1979. The JAWF, comprised of NWS/CAC and USDA employees, was created a few months earlier. Under a NWS reorganization in 1995, CAC became the Climate Prediction Center.

(1) Weekly Text Products

The WWCB begins with a text of “U.S. Weather Highlights” a descriptive summary of significant weather events (i.e., droughts, floods, freezes, temperature extremes, snowfall, severe weather, etc.) that affected agriculture during the preceding week (Sunday - Saturday). These highlights provide the framework for the “National Agricultural Summary” section of the bulletin. This national summary contains information on field crop progress and condition that is obtained from detailed weather and crop summaries prepared by the SSOs and transmitted each Monday afternoon to the crop statistician at NASS in Washington, D.C. A shorter version of these individual state reports is published in the “State Summaries of Weather and Agriculture” section of the WWCB. The state reports usually discuss crop-weather conditions relating to fieldwork and crop development, pest and disease outbreaks, soil moisture levels, crop progress, and pasture and livestock conditions.

The “International Weather and Crop Summary” portion of the WWCB contains information on weather and crop developments in major crop-growing areas worldwide. These international summaries provide an early alert of weather conditions that affect yield potential on a regional scale, and ultimately have an impact on United States supplies and prices for agricultural commodities. Areas that are covered in the international section of the WWCB year-round include: Europe, Western former USSR, Eastern Asia, Southeast Asia, Australia, and South America. Areas with seasonal coverage include: Northwestern Africa, South Africa, the Middle East, the New Lands region of the former USSR, South Asia, Mexico, and Canada.

(b) National and International Charts

High-quality weather and climate data serve as the core for the continued success of the WWCB. Most of the various charts (maps) and tables in the WWCB are obtained from the NWS/CPC. For the United States, charts containing analyzed precipitation and temperature data are published each week, while charts of precipitation, percent of normal precipitation, average temperature, and departure of average temperature from normal are published for each month and season (December - February, March - May, June - August, and September - November). For international areas, charts of precipitation are published each week, while charts of precipitation, percent of normal precipitation, average temperature, and departure of average temperature are published monthly. The weekly charts provide information on weather conditions currently affecting crop development. The monthly and seasonal charts provide an indicator of longer-term developments.

The WWCB includes agricultural meteorological data and derived parameters, including soil temperature, pan evaporation, growing degree day (GDD) accumulations for corn, Western U.S. snow pack information, the Palmer Drought Severity Index, the Crop Moisture Index, and the Drought Monitor. A map of weekly average soil temperatures at a depth of 4 inches is published during the spring (March - June), providing guidance to farmers on when soil temperatures have
reached high enough levels to begin planting field crops such as corn, soybeans, cotton, and sorghum. A U.S. map containing daily pan evaporation measurements averaged over the week from a standardized NWS Class “A” pan device is published for available locations from May - September. Pan evaporation measurements are used to estimate the amount of evaporation from lakes and reservoirs, to compute potential evapotranspiration and crop-water needs, and for irrigation.
Table 2. Regular Features In The Weekly Weather and Crop Bulletin  
(w = weekly, m = monthly, s = seasonal, a = annual)

**Text:**
- U.S. Weather Highlights .......................................................... w/s/a
- U.S. Weather and Crop Summary .................................................. m
- National Agricultural Summary .................................................. w
  - Spring Wheat, Oats, and Barley (April - September) .................. w
  - Rice, Sorghum, Corn, Cotton, and Peanuts (April - November) ...... w
  - Soybeans (May - November) .................................................. w
  - Winter Wheat (September - November and April - August) .......... w
  - Sugar Beets (April - May and September - November) ................. w
  - Sunflowers (May - June and September - November) .................. w
- U.S. Crop Production Highlights ................................................. m/a
- State Summaries of Weather and Agriculture (April - November) ...... w
- State Summaries of Weather and Agriculture (December - March) ...... m
- Water Supply Forecasts for the Western United States (January - March)
- International Weather and Crop Summary (major crop areas) .......... w/m
- Special Articles and Charts ....................................................... as needed

**National Charts:**
- Precipitation .............................................................................. w/m/s/a
- Percent of Normal Precipitation ................................................ m/a
- Average Temperature ................................................................. m/a
- Departure of Average Temperature from Normal ........................ m/s
- Extreme Minimum Temperature (September - April) .................... w
- Extreme Maximum Temperature (April - September) .................... w
- Snow Depth (December - March) ................................................. w
- Average Soil Temperature, 4-Inch Depth, Bare Soil (March - June) ...... w
- Pan Evaporation (May - September) ........................................... w
- Growing Degree Days (May - October) ........................................ w
- Crop Moisture Index (April - October) ......................................... w
- Palmer Drought Severity Index (April - October) .......................... w
- Additional Precipitation Needed to End Drought (April - October) ....... w
- Drought Monitor ................................................................. w

**International Charts (major crop areas):**
- Precipitation .............................................................................. w/m
- Percent of Normal Precipitation ................................................ m
- Average Temperature ................................................................. m
- Departure of Average Temperature from Normal ........................ m

**National Tabulations:**
- Weather Data for Selected Cities .............................................. w
- Weather Data for Selected Locations in the Delta and Bootheel ........... w
- Precipitation and Temperature ................................................... m/s
- Crop Progress: Planting, Development, Harvesting (April-November) ... w
- Crop Condition (April - November) ............................................. w

**International Tabulation:**
- Precipitation and Temperature ................................................... m
scheduling. Charts containing cumulative weekly GDDs for U.S. corn are featured during the growing season. Departure from normal GDD maps are also calculated in order to monitor the seasonal progress of the corn crop. The GDD index for corn was first introduced into the bulletin in 1969, as a more accurate measure of corn growth and maturity, instead of the accumulation of a certain number of calendar days. A description of the GDD concept for corn is given by Felch, 1972, and Ramirez and Bauer, 1974.

Drought monitoring and assessment is of paramount importance when determining the impact of weather on agricultural production. Furthermore, the severity and duration of drought determines the degree to which agricultural production is impacted. Since it takes weeks or months for drought conditions to develop, drought severity not only depends on current conditions, but antecedent weather as well. The Palmer Drought Severity Index (PDSI) was introduced into the WWCB in 1961 by Wayne Palmer, as an index of meteorological drought (Palmer, 1965). Today, the PDSI remains a vital portion of the publication, serving as a useful tool in U.S. drought monitoring. Weekly maps of drought severity are generated by computing the PDSI for each of the 344 climate divisions in the continental United States. The PDSI is calculated from long-term records of precipitation and temperature, the available water content of the soil, and the normal climate of an area. The PDSI provides spatial and temporal representations of historical droughts and indicates the availability of water supplies for irrigation, reservoir and pond levels, range conditions, and potential for wildfires.

While the PDSI evaluates the scope of prolonged periods of abnormally dry weather, it does not evaluate short-term moisture conditions that are needed for agriculture. A period of rain for a couple of weeks could be very beneficial for crops, but would not be nearly enough to replenish depleted soil moisture reserves or restore low reservoirs to a near-normal level. In order to evaluate the short term moisture conditions for agriculture during the growing season, Palmer (1968) developed a second index called the Crop Moisture Index (CMI). The CMI was first published in the WWCB in the April 15, 1968, issue. Each week, maps containing CMI values for each climate division in the continental United States as well as analyzed values of the CMI are published. The CMI index responds rapidly to changes in temperature and moisture conditions during the growing season. As a result, the CMI is not a good long-term drought monitoring tool. Furthermore, the CMI is not applicable to germinating and shallow-rooted crops, or for cool season crops when temperatures are averaging below 55 degrees F.

In 1999, representatives from USDA, DOC, and the National Drought Mitigation Center met to discuss the need for a new national drought product. These discussions led to the creation of the U.S. Drought Monitor, which is assembled by a rotating team of nine lead authors, who look at several drought indices, including the PDSI and CMI, to produce a national drought product that incorporates agricultural, hydrological, and wildfire concerns. The Drought Monitor, which is updated weekly, has appeared in the WWCB since March 2000.

(3) National Tabulations

Each week during the growing season (April - November), tables containing state and national information on crop progress and condition are published in the WWCB. These tables are compiled at the NASS headquarters in Washington, D.C., and are based on information that is received each week from the SSOs. The crop progress tables contain information on the percentage of crops that were either planted or harvested during the week ending Sunday, and the percentage of crops in various phenological stages, such as silking of corn or heading of wheat. Crop progress tables are provided for each of the major field crops, including winter wheat, spring wheat, corn, sorghum, soybeans, barley, oats, peanuts, sunflowers, sugar beets, cotton, and rice. Each table contains information for only those states where a majority of the crop is grown. Information on crop progress from the previous week, the previous year, and the 5-year average is included in the table. Each table contains a summary of national crop progress that is weighted by state, and based on either the planted (for planting progress table) or harvested (for harvest progress table) acres for the previous year. Statistics on crop and
pasture condition are provided by crop reporters that are instructed to “report the conditions of the crop now, as compared with the normal growth and vitality you would expect at this time, if there had been no damage from unfavorable weather, insects, pests, etc.” The normal condition of the crop may vary from one location to another due to soil and climate differences, crop varieties, and cultural practices. There are five categories of condition: very poor, poor, fair, good, and excellent. Each table contains a summary of national crop conditions that are weighted by state, and based on planted acres for the previous year.

Each week, a data table containing precipitation (in inches) and temperature (in degrees Fahrenheit) for selected cities in each of the 50 U.S. states is published in the WWCB for the period ending on Saturday. These data are provided by the NWS/CPC. This “Selected Cities” table provides a closer look at weather conditions that are locally affecting agriculture. In addition to temperature and precipitation data, the table contains information on relative humidity and episodic weather events. Around the beginning of each month, tables containing precipitation and temperature data for the previous month are published for selected cities in both the United States and some international locations. For the United States, the data are in English units and consist of calculations of average monthly temperature, departure from normal monthly average temperature, total monthly precipitation, and departure of monthly precipitation from normal. Data for selected cities in international countries are in metric units. The monthly temperature information (in degrees Celsius) consists of calculations of average maximum temperature, average minimum temperature, extreme maximum and minimum temperatures, monthly average temperature, and the departure from normal monthly average temperature. Precipitation data (in millimeters) includes the total observed monthly precipitation and its departure from normal (based on 1971-2000 data).

While the information contained in the “Selected Cities” table is highly useful, these sites do not provide satisfactory coverage for some agricultural areas. Such areas are found in the Mississippi Delta and the Missouri Bootheel region, where agricultural weather data collection sites exist, but are beyond the responsibility of the current NWS basic reporting network. In order to establish a linkage between these two networks, a table containing “Weather Data for Selected Locations in the Delta” was added to the WWCB in February 1999. Additional data for the Missouri Bootheel region was added in August 2000. Data contained in the table is provided weekly by the Mississippi State Delta Research and Extension Center, the Southern Regional Climate Center, and the University of Missouri. The table contains weather data similar to that found in the NWS “Selected Cities” table, except values of soil temperature (at the 4-inch depth in degrees F) are substituted for the relative humidity values.

**ECONOMIC BENEFITS**

Meteorological conditions influence important farming operations such as planting and harvesting, and greatly influence yield at critical stages of crop development. As a result, the statistics contained in the WWCB keep crop and livestock producers, farm organizations, agribusinesses, state and national farm policy-makers, government agencies, and foreign buyers of agricultural products appraised of worldwide weather-related developments and their effects on crops and livestock. The WWCB provides critical information to decision-makers formulating crop production forecasts and trade policy. Furthermore, tracking weather and crop developments in countries that are either major exporters or importers of agricultural commodities keeps the agricultural sector informed on potential competitors. The bulletin also provides timely weather and crop information between the monthly Crop Production and World Supply and Demand Estimate reports, issued by NASS and WAOB, respectively.

Crop and weather reports are especially important in farming areas. A wet planting season may prompt farmers to switch to another crop. A poor grain harvest may affect livestock feeding patterns. A regional drought can boost planted acres elsewhere to offset the expected production decline, and government policymakers may adjust farm programs to accommodate changing conditions. Thus, agricultural statistics contained in the WWCB keep farmers, consultants, public agencies, and private organizations aware of changing crop developments.
within each state and across the nation. Another important user of agricultural statistics is the analyst. The analyst uses statistics on crop progress and crop condition to make crop-yield projections, and to determine the local and national economic impacts of changes in crop developments, including their potential impacts on U.S. agricultural commodity prices.

OTHER IMPORTANT ISSUES

The main emphasis of the **WWCB** is on macro-scale (regional) applications of agricultural meteorology, as opposed to micro-scale field applications. While the **WWCB** was originally designed to maintain a current awareness of weather and crop conditions both nationally and internationally, the long history of the publication makes it an excellent climatological record. This extensive history provides a reference source that is rich in climate and agricultural information, which is essential for episodic-events monitoring and analog-year comparisons. The value of information provided to data users depends on the speed of delivery. Although the **WWCB** is available by subscription, quicker access to the information can be obtained through the JAWF Web site at [http://www.usda.gov/agency/oe/oaob/jawf/wwwcb.html](http://www.usda.gov/agency/oe/oaob/jawf/wwwcb.html). Both NASS and WAOB maintain an archive of reports and databases on the Internet at [http://usda.mannlib.cornell.edu](http://usda.mannlib.cornell.edu).

CONCLUSION

For over a century, the *Weekly Weather and Crop Bulletin* has provided a current and reliable source of information on meteorological and agricultural developments within the United States. The expansion of coverage into international areas in the 1970's, along with the creation of the Joint Agricultural Weather Facility in 1978, made the **WWCB** an invaluable source of information on global weather and agriculture, further increasing the economic benefit of the publication.

REFERENCES


### RESOURCE PERSONS

<table>
<thead>
<tr>
<th>Thomas L. Puterbaugh</th>
<th>Bradley R. Rippey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supervisory Meteorologist</td>
<td>Agricultural Meteorologist</td>
</tr>
<tr>
<td>United States Department of Agriculture</td>
<td>United States Department of Agriculture</td>
</tr>
<tr>
<td>World Agricultural Outlook Board</td>
<td>World Agricultural Outlook Board</td>
</tr>
<tr>
<td>14th and Independence Ave. SW</td>
<td>14th and Independence Ave. SW</td>
</tr>
<tr>
<td>Washington D.C. 20250-3812</td>
<td>Washington D.C. 20250-3812</td>
</tr>
<tr>
<td>phone: (202) 720-2012</td>
<td>phone: (202) 720-2397</td>
</tr>
<tr>
<td>fax: (202) 690-1805</td>
<td>fax: (202) 690-1805</td>
</tr>
<tr>
<td>e-mail: <a href="mailto:tputerbaugh@oce.usda.gov">tputerbaugh@oce.usda.gov</a></td>
<td>e-mail: <a href="mailto:brippey@oce.usda.gov">brippey@oce.usda.gov</a></td>
</tr>
</tbody>
</table>

Note by the Co-ordinator:

Colour photos related to this case study are available.
The assessment of the effect of climate change on such natural resources as water and agroclimatic ecosystems, separate natural ecosystems, and the attempt to identify possible adaptation strategies are based on IPCC recommendations, regional policies and expert estimates. The increase in the carbon dioxide concentration, with all other factors being favourable, will have a beneficial effect on the growth and yield of most cultivated crops.

However, an increase in the number of days with high temperatures during the spring-summer period is expected to be unfavourable for the crops and pasture. Extreme hot conditions will decrease livestock productivity. Mountain pastures are expected to shift their boundaries to higher altitudes. Actions in response to climate change in agriculture should be coordinated with socio-economic measures as well as with desertification and drought control measures to ensure the sustainable and secure development of the Republic.

Recommendations on adaptation to climate change are primarily focused on productivity. Adaptation measures include: optimizing land reserve use, applying the water-saving technologies, land reclamation, optimization of the cropping structure, introducing drought-resistant varieties, increasing effectiveness of fertilizer application and plant protection agents, recovery of the natural vegetative cover, phytoreclamation of pastures and artificially increasing rainfall.

At the present time, the Aral zone is subject to all main processes of desertification: nudging of saturated by salt soils of dries bottom of sea; land salinity, loss of wood plantings, tugaies and vegetative cover; drought of lakes and ponds; land degradation; to strengthening of deflation and salt-dust-transfer; to increase of mineralization of surface and ground water; flooding of irrigated and adjoining to it lands; saline of soil etc. The tendency of reduction of soil fertility is preserved. The general area of lands in Republic of Karakalpakstan with low fertile (from 20 to 60) numbers on 240 thousand has increased.

The quantity of dust phenomena in the west of Central Asia for period of supervision (1965-1988) was increased from 1724 to 7766 per annum. The zone of loss of 80-90% of salt-dust particles, carry out from dried bottom of sea and salt marches, practically covered the all Amudarya delta to Nukus. The most considerable from abiotic factors the balance of halogeochemical cycle in region is infringing. At high-grade functioning the Aral sea executed the role of natural salt receiver. The Amadarya and Sirdarya rivers brought in sea more than 25 mln. tons of salts annually. They accumulated inaquatory were involved in processes of air carry with precipitation and aerosols, partially filtrated with ground flow, accumulated on bottom of sea in small water lagoons and bays. Especially heavily the irrigation in Republic was developed in 1975-85. For this period was involved the salinity and difficult meliorative lands. That was one of...

---

1Dr. Vladimir Usmanov, Uzbekistan, submitted this summary report based on the 1999 Initial communication of the republic of Uzbekistan under the UN Framework Convention on Climate change. This report is not in the recommended format for case studies, it was not edited but included here for information purposes (Note by Coordinator).
the reasons of sharp increase (on 0.8 mln. ha for the latter of 15-20 years of area of salinity lands.

At present, in Uzbekistan to process of salinity in this or that measure is subject of 2.0 mln. ha of high productivity lands, from which 0.85 mln. ha with average and strong salinity. On 30-50% the contents of humus-main parameters of fertility was lowered. At present the soils with low security of humus (from 0.4 to 1.0 %) take about 40% from areas of irrigated lands.

Continuing the many years the dominance of monoculture of cotton, absence of necessary system of rotations (based on soil-protection system of agriculture, the insufficient development of animal industries (that has served by reason of deficit of organic fertilizers) has caused the necessity of application in wide scales of mineral fertilizers and pesticides. All this in the end has resulted in the destruction of natural biological processes, degradation of natural regulating gears, conversion of soil from difficult ecological system in substrate for transmission of introduced mineral connections to roots of plants.

Resource person

Dr. Vladimir Usmanov
SANIGMI
K. Makhsumov, 72
TASHKENT 700052,
Uzbekistan
Annex 14

Agrometeorological products and their economic benefits in the Russian Federation

Summary report submitted by Ms. Olga Ustinova, Russian Federation

Agrometeorological products

The essential operation problem of any national Hydrometeorological Service is the decrease of unfavourable weather damage and rise in the efficiency of any branch of economy, including farming systems, forestry and livestock, at the cost of rational employment of natural resources. Rational employment of the natural environment provides for sustainable management of economy based on the information obtained.

Any management of farming systems, forestry and livestock is valuable and sustainable in case of a certain profit obtained by the branch as a result of management decision making, not necessary ecomonic. For successful application of any hydrometeorological information, including agrometeorological information, three lines of activities in this field are essential. As applied to agrometeorology, they are the following:

First, the theoretical studies on developing economic-agrometeorological models of optimal decision making on the basis of agrometeorological information.

Second, the applied researches concerning application of agrometeorological information and agrometeorological forecasts in different branches of agriculture.

Third, the development of methods for assessing the economic effect of agrometeorological information applied in farming systems, forestry and livestock with the account of data on the sensitivity of different areas of application to weather conditions and climate and the losses associated with adverse weather conditions.

It is clear that the success of any application and, all the more, sustainable management, depends on the success of marketing studies and the ability to evaluate the competitiviness of agrometeorological information (Ya.Yu.Alshansky, 1997; A.G. Prosvirkina et al.,1995).

On the basis of a variety of forms of primary agrometeorological observations in the Roshydromet network, mainly three types of the final analytical product (current, prognostic and regime(climatic)-reference) are prepared and presented to the consumers.

The practice of hydrometeorological support shows that the highest effect is observed when using information about hazardous meteorological and agrometeorological phenomena and unexpected weather changes, on the basis of which this or that management decision is taken for sustainable development of farming systems or other branch of economy.

It is clear that the activities of practically all industrial and economic structures in any branch of economy depends on environmental conditions. However, the degree of this dependence is different and it is explained, first of all, by a specific character of production. Agriculture is among 5-6 key branches of RF economy accounting for practically the whole volume of losses which can be prevented in case of current and wide application of

---

1Ms. Olga Ustinova, Russian Federation, submitted this summary report in October 2000. The Coordinator suggested re-formatting and clarification but received no reply. The unedited summary report is included here for information purposes. Only the title was added and minor format modifications were made to fit this summary report into the overall Case Study Report. It is not a case study in the recommended format.
hydrometeorological information and management decision making, for which it is especially valuable.

According to Bedritsky A.I. (1995), agriculture is most open in respect to the environment, and hence, most subjected to the impact of hydrometeorological factors (60% of the total economic loss as a whole), it is followed by energetics, transport and construction activities (from 6.8 to 9%). In other countries this ratio is different, however, it is constant in the following: agriculture is highly subjected to the climate and weather impact. Therefore the essential line is regular monitoring of the impact of agrometeorological applications on sustainable management of farming systems, forestry and livestock. This problem is very important for the CAgM WMO activities and, simultaneously, very difficult.

For more effective activities of agricultural facilities, the agreement is concluded between the Roshydromet and the Ministry of Agriculture stipulating the single procedure to render hydrometeorological (agrometeorological) services in the territory of Russian Federation, on the basis of which different ways of management decision making are possible.

These data include:

- information about natural hydrometeorological phenomena, dangerous for agriculture, including strong heat, extreme fire danger, glaze ice-hoarfrost, intensive precipitation, strong wind, snowstorms, hot winds, expected sudden variations in the daily mean air temperatures, high water levels (in flood, rain flooding), earth flows;
- 1-3 day forecasts of natural hydrometeorological phenomena (storm rains, strong winds, floods, typhoons, snow-falls, droughts, dust storms, severe frosts and heat);
- 1-3 day weather forecasts in the RF territory;
- information about extremely high environmental contamination;
- forecasts of expected winter cereal crop conditions at the beginning of vegetation in RF;
- forecasts of productive water reserves in soil at the beginning of spring farm operations;
- forecasts of the yield and the gross harvest of principal crops (winter wheat and rye, spring wheat, spring barley, maize, buckwheat, all cereals and leguminous crops, sunflower seeds, sugar-beet roots, potato tubers for economic regions and Russian Federation as a whole);
- information about winter cereal crop conditions in autumn after the termination of vegetation for economic regions and Russian Federation as a whole;
- review of agrometeorological ten-day period conditions in the RF territory (with a map of the ten-day period and monthly precipitation amount attached);
- agrometeorological annual book;
- series of reviews on environmental contamination conditions from different sources;
- monthly information about natural weather phenomena, hydrometeorological conditions and their impact on the key branches of economy.

The above forms of information are available for the Ministry of Agriculture free of charge because Roshydromet is the state organization. Besides, in accordance with the agreement achieved, Roshydromet provides the Ministry of Agriculture with the following special information:

- weather forecasts for ten-day, month, heating and vegetation periods;
- average regional productive water reserves in soil;
- sum temperature accumulation in a vegetation period over certain limits;

- information about winter cereals conditions in autumn after the termination of vegetation;

- weekly, ten-day, monthly, seasonal and annual reviews of agrometeorological conditions in the RF territory;

- forecasts of expected winter cereals conditions at the beginning of vegetation, productive water reserves in soil at the beginning of spring farming operations, yield and gross harvest of the key crops in the RF territory;

- actual data of many year (10, 25 years and more) observations of weather and soil conditions;

- science-technical and reference materials on hydrometeorological conditions in the territories.

- forecasts of pollutant propagation as well as pollutant concentration in the atmospheric air (water) based on ejections and discharges under emergency situations;

- 1-3 day weather forecasts for the RF territory.

Economic Benefits of Agrometeorological Applications

Proceeding to the particular methods and technologies of agrometeorological observations, the use of information is to be noted for strategic decision making; primarily, it is related to the problems associated with climate and climate change (O.D.Sirotenko et al., 1998; J.R.Bruce, 1991; C.Rosenzweig et al., 1994 and etc.).

The developed simulation system CLIMATE-SOIL-YIELD (O.D.Sirotenko et al., 1998) allows to obtain information for the appropriate decisions. The system involves:

- dynamical models of the kye crop yield formation;

- simulation model of energy and mass exchange in the system soil-plant-atmosphere;

- soil database in the whole territory;

- set of programmes to develop the comprehensive scenarios of climate change.

The system allows to estimate the impact of proper climate parameters and variations in the greenhouse gas (CO2 and O3) content and soil fertility on agriculture productivity. The information obtained was included in the first and the second national RF reports on climate change.

When decision making at a governmental level, the prompt account of Roshydromet information on climate change allows to take the preventive measures which considerably decrease the costs of overcoming the adverse climate change consequences. Besides, in the context of Russia execution of obligations within the framework UNO Convention on climate change, the estimates are essential of the expected effect of measures, taken in response to climate change, on the branches of economy (first of all, agriculture). Such estimates formed the basis of the Programme of agriculture development in Russia for 2000-2003 and longer periods. Calculations according to a given scheme show that in case of the global temperature rise in the RF territory, the number of droughts, especially in the south of Russia, will increase, the redistribution of territories under forest will happen, the territories subjected to desertification will appear. All this requires the corresponding concept of country development to be elaborated.

Agroclimatic information is most widely used in solving the operative problems of farming systems for their sustainable management. First of all, it is the technology of
assessing agroclimatic resources of crop growing developed in Roshydromet (V.A.Zhukov, S.A.Danielov, 1998; E.K.Zoidze, 1997). This technology realizes an idea of the sequential ten-day diagnostics observed in the many year cross-section of weather situations and the assessment of its correspondence to the crop requirements using the algorithms of GIS image and element recognition. Such an approach allows to describe the climate-crop system behaviour with the help of the Markov chains and to give the probability forecast of different unfavourable weather conditions and their impact on agriculture as a whole. The crop yield losses (expressed in absolute values) in anomalous years and their probability estimates are the essential information for decision making in agriculture. This technology allows

- to give the agroclimatic forecast (in analogy) of most probable development of weather conditions as applied to a specific crop and its possible yield losses in case of this or that adverse weather situation;

- to estimate the natural-resource potential as applied to the key crop growing in a regular network node in the administrative region, on the average, or in the area by calculating potentially and climatically supported crop yield;

- to calculate the optimal structure of sown areas;

- to restore the fields of main hydroelements with the account of their space variability and microclimatic corrections;

- to establish the climatically appropriate areas of the key crop growing.

Systems of the "CLICOM" type serve the information basis for applying these technologies.

The traditional line of agrometeorological applications is the use of crop yield and gross harvest forecasts, on the basis of which a series of management decision making in agriculture is adopted, from the terms of harvesting to the purchasing price (A.D.Kleschenko et al., 1996).

There are many different methods and technologies in various countries. Among them is the MARS system developed by the European Commission for the European countries (P.Vossen, 1996). The perspective technology developed in Roshydromet has to be noted (V.M.Pasov, 1996). The perspective of this technology consists in the isolation of a stable "useful signal" associated with the crop yield dynamics over the 40-50 year observational period. On the basis of this "useful signal" obtained for different environmental variables the so-called complex parameters are calculated which characterize the peculiarities of crop growing in a forecasted year and later; they are the predictors in statistical models of yield forecast. The developed methodology (using suggested algorithm) allows to forecast the yield of any crop not depending on its biological peculiarities and climate in the territory, to use a unified set of variables for the whole territory, to specify the observed correlations automatically every year, to calculate the step-by-step yield forecasts.

One of the merits of this method is the possibility to increase the period of forecasts in good time (from 1 to 8 months), that makes the method unique and has high prospects for sustainable management of farming processes.

Utilization of satellite information, primarily, for assessing crop conditions, crop productivity and anomalous conditions (drought, frost) belongs to the same line of activities A.D.Kleschenko et al., 1995; F.Kogan, 1995; W. Shili, 1996 and etc).

Agrometeorological applications have played and play now an important role in the maximum product (yield) management of a specific crop. There is a great quantity of different techniques considering weather conditions in the conduction and the correction of the following agrotechnical measures: the terms of sowing, winter crop maintenance in winter, resowing and
subsowing of damaged winter crops, mineral nutrition in various vegetation periods, correction of the variety structure, protection from diseases and pests, the terms and the course of harvesting and so on (A.P. Fedoseev et al., 1976).

These recommendations are highly perspective from the point of view of developed measuring information-prognostic computer systems for agrometeorological monitoring and special service (ELAGR (RF) and METOS (Austria)).

The use of these systems provides for the 15-20% yield rise with the decrease in material costs by 10-15% and the increase in the level of economic production safety.

Considering the third line, i.e. assessment of economic efficiency of agrometeorological applications, the complexity of such calculations has to be emphasized. In most cases the question is their potential effect.

The practice of hydrometeorological support shows that the information about dangerous meteorological phenomena, sudden changes in weather conditions has the highest economic effect, the active impact on different hydrometeorological processes is also effective (A.I. Bedritsky, 1995). Antihail operations to protect the crops from hail damage have been initiated in RF more than 30 years ago and now they are performed in the territory of 1.8 mln ha. The available experience of anti-hail operations demonstrates that their efficiency is not less than 75%, on the average. It means that hail damage in the protected territory decreases 3-4 fold as compared to the many year averaged loss in the same area before antihail operations.

The successive frost forecast for May 1994 in Omsk region allowed the early vegetable crops to be planted at later periods; the prevented loss amounted to 1.5 mln US dollars.

Resowing of winter crops in spring based on agrometeorological recommendations is highly effective for RF agricultural production.

The survey by questionnaire among national meteorological and hydrological services (NHMS) on the economic efficiency (V.A. Trenin, 1997) had showed that the conventional application effect of hydrometeorological information for various countries by 3-30 times exceeds the budgetary appropriations for NHMSs. Agriculture is the first for expected effect in most countries.

Resource person

Ms. Olga Ustinova
Head of Marketing Researches Laboratory
ARRIAM
Lenin Street, 82
249020 OBNINSK Kaluga Region
Russian Federation
Phytophthora cinnamomi has been reported on several oak species in France: *Qercus rubra*, *Q. robur*, *Q. suber* and *Q. ilex*. In most infected stands, trees exhibit bleeding trunk cankers, whereas in a few cases, *P. Cinnamomi* could only be isolated from soil. The annual development of trunk cankers in red oaks was studied in 5 locations of south-western France over a 30-year period, by dendrochronological methods. A general increasing trend of the canker size was observed, except for a very sharp decline in 1985. This coincided with an exceptionally cold winter. Indeed, *P. Cinnamomi*, with a tropical origin, is very sensitive to frost. In order to map disease hazard, we considered that the extension of the disease is primarily limited by cold temperatures which condition the ability of the fungus to survive in trunks and thus to cause perennial cankers. The survival of *P. Cinnamomi* inside trunks was modelled in relation to air temperatures. Several frost index were mapped over France which allowed to define low to high hazard zones. The known distribution area of the disease was included in high hazard zones but other zones with high hazard were identified, which should be paid particular attention.

**Resource person**

Mrs. Victorine Pérarnaud  
Responsable de la subdivision Agromet  
SCEN/Services/Agrométéorologie  
Météo-France  
42 Avenue Coriolis  
31057 TOULOUSE Cedex  
France