World Meteorological Organization

Commission for Agricultural Meteorology

Expert Team 3.2

Agricultural decision support and extension services on climate extremes

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1. Introduction

The 16th Session of the WMO Commission for Agricultural Meteorology (CAgM) was held in Antalya, Turkey, from 10 - 15 April 2014. During the session four Focus Areas (OPCAME) were defined and Expert Teams (ET) were elected to carry out the defined Terms of Reference (ToR). Under Focus Area 3 ‘Natural hazards and Climate Variability/Change in Agriculture’ three ETs were formed. ET 3.2 focused on ‘Agricultural Decision-Support and Extension Services on Climate Extremes’. It addressed the following four ToR’s requested by the Management Team of WMO CAgM:

(a) Report on existing material on agricultural decision support and its value for agricultural stakeholders’;
(b) Update the list of successful case studies and deficiencies of agricultural decision-support and extension services;
(c) Develop guidance material on the basics of decision-support and extension services and its value for agricultural stakeholders;
(d) Report and make recommendations to CAgM on maintaining and enhancing agricultural decision-support and extension services;

The ET 3.2 convened at the WMO headquarters in Geneva, from 3-8 February 2016. During this meeting the work to be done by the ET was discussed and tasks were divided between its members. The report describes the main outcomes from the work and provides hereunder the main recommendations to WMO-CAgM on agricultural decision-support and extension services for coping with climate extremes.

Recommendations:

The main recommendations to CAgM resulting from this report are as follows:

a) To investigate the reliability of seasonal forecasts for a large number of locations, and determine the credibility of seasonal forecasts.

b) To improve the seasonal forecast information, and make it more meaningful than a simple probabilistic rainfall forecast.

c) To evaluate different communication strategies and determine how effective these strategies are in reaching the stakeholders.

d) To evaluate examples of successful communication of agro-meteorologically based agricultural advice and derive a common strategy for development and communication of agricultural advices to the potential users.

e) To learn lessons from past and current CFS’s, and to stimulate CFS programmes in other countries where extension staff and farmers are not yet familiar with the potential applications of agro-meteorological information and forecasts.

f) To continue the activity on updating the list of successful case studies and deficiencies of agricultural decision support and extension services.

2. Agricultural decision-support and its value for agricultural stakeholders

The first item under ToR 3.2a (Report on existing material on agricultural decision support and its value for agricultural stakeholders) was carried out by reviewing Chapter 17 of the 2012 updated version of the Guide to Agricultural Meteorological Practices (GAMP)[1]. This chapter is entitled '*Communicating agro-climatological information, including forecasts, for agricultural decisions*' and primarily focuses on the communication of climate information for on-farm planning. The challenges of effective communication of agro-meteorological information are reviewed, and recommendations for bridging identified gaps are provided. The following summarizes the most relevant issues from GAMP Chapter 17.

Summary of Chapter 17 of the Guide to Agricultural Meteorological Practices

2.1 Introduction

Agricultural production is severely affected by seasonal variability of weather. It is widely recognized that the use of seasonal forecasts has the potential to improve agriculture, but these forecasts are not effectively exploited so far. To make better use of climatic information requires effective mechanisms for its communication to its users, such as farmers, agri-business, transportation, insurance companies, etc. Obstacles to the use of climate information range from understanding and modelling the complex climatic systems, to effective communication systems. Most farmers who have to make agricultural decision do not include climate information on routine base. This is related to the site-specific and complex agricultural systems as well as the lack of effective decision support systems. But the lack of appropriate communication has been shown to be the key weakness in the use of seasonal forecast information in several location-based studies. Most communication channels rely on extension services, media, agro-meteorological bulletins, etc. It remains a challenge to guarantee the use of seasonal forecasts in agricultural decision making. The GAMP Chapter 17 reviews the challenges of effective communication of climate information, and recommends improvements for better communication between climate service developers and agricultural communities.

2.2 Use of Climate Information in Agriculture: Framing the Decision Problem

Agricultural problems are differently framed by farmers, researchers, information providers and policy makers. These different views are shaped by knowledge and views of the world, which are affected by attitude, culture and the organization of knowledge. Time lines and language may be different between different stakeholders. Effective communication of climate information can be framed by the following questions:

(a) Is the information relevant for decisions in the particular agricultural system?

(b) Are the sources/providers of information credible to the intended user?

[1] *Pulwarty, R.S., O.O. Segun and P. Zorba. 2012. Communicating agro-climatological information, including forecasts, for agricultural decisions. P. 17-1 – 17-15 in Guide to Agricultural Meteorological Practices (GAMP) 2010 Edition (WMO-No.134), Updated in 2012. WMO, Geneva.*

(c) Are farmers receptive to the information and to research?

(d) Is the research accessible to the policymaker or decision-maker?

(e) Is the information compatible with existing decision models and farming practice?

(f) Do decision-makers have the capacity to use information?

Existing studies on climate information for use in agriculture have all concluded that information about rainfall amounts and distribution is the most relevant to agriculture in the tropics. To meet this demand key information needs include:

(a) Adequacy of rainfall amounts, including deficits and excesses, to meet demands for specific crop types.

(b) Early warnings of potentially poor seasons.

(c) Key management decisions such as planting dates, crop choices, and diversifying for risk reduction.

Clearly, such information demands require collaboration between national meteorological services and other institutes involved in agricultural research, development and extension. Crop simulation modelling should be used to evaluate different agricultural management decisions based on historical weather patterns and seasonal forecasts. Such models can be run for different crops and management types, and provide a means to evaluate the potential impacts of the management options. A problem thereby is that the traditional forecasts based on the El Niño/Southern Oscillation (ENSO) Sea Surface Temperature (SST) anomalies lack information about the expected rainfall distribution. This largely hampers the possibility of correctly modelling the expected crop yields. The crop model simulations should be complemented with knowledge of historical climatic events, such as previous ENSOs, and their impacts on agricultural practices, including specific crop yields and economic values.

Effective use of climate information requires a good environment for its effective use. Relevant questions that need answers for defining the right conditions for effective climatic information use are:

(a) Physical/material resources: What physical climate risks, social skills and productive resources exist?

(b) Social/organizational capacity: What are the relations and organizations among information providers and users?

(c) Behavioural incentives: How does the community view its ability to create change?

The ultimate goal of climate services to farmers should be accurate prediction of climate fluctuations that lead to improved management decisions, which reduce vulnerability to extreme weather conditions. The improved management decisions depend on communication, which requires institutional support and a favourable policy environment.

According to Hansen (2002)[2] the following five conditions are required for successful forecast application:

(a) Decision-maker vulnerability and motivation. Forecast information is useful only when it addresses a need that is real and perceived. Decision-makers must be aware of climate risk and its impacts, and motivated to use forecasts to manage this risk.

(b) Viable forecast-sensitive decision options. Benefits are conditioned upon the existence and understanding of decision options that are sensitive to incremental information in forecasts, and compatible with goals and constraints.

(c) Predictability of climate fluctuations. Relevant components of climate variability must be predictable in relevant periods, at an appropriate scale, with sufficient skill and lead time for decisions.

(d) Communication. Use of climate forecasts requires that the right audience receives, understands and correctly interprets the right information at the right time, in a form that can be applied to the problem(s) that require a decision.

(e) Institutions and policy. Sustained operational use of forecasts requires institutional commitment to provide forecast information and other support, and policies that support provision and use of climate forecasts.

Communication channels

The effective communication of seasonal forecasts requires a number of factors, including communication channels, stakeholder groups, stakeholder awareness, and language and terminology. There is a great disparity between communication infrastructure between countries, but also between the relevant stakeholders. Research generally has a much better and more effective communication means than extension services and farmers in developing countries, where rather conventional communication means are used. New innovations of mobile phone services, local internet provisions (e.g. internet kiosks in India) are novel ways of communication that go beyond the more traditional radio broadcasts and agro-meteorological bulletins. However, many farmers are probably better reached through radio broadcasts than by other means, as they are already familiar with this type of information sharing. A number of examples from African countries indicate that communication between the national meteorological services and the farming communities is either poor, insufficient or too late for effective management decisions. Generally, there is a need for better training and use of extension staff to improve communication and dissemination, as well as improved relations with the media.

Capacity development for effective communication

In a number of countries the meteorological services have programmes that collaborate with agricultural research for the uptake and use of seasonal forecasts for agricultural decision making. Examples are Australia, USA, CLIMCAG-West Africa (a consortium of West African and European countries), CLIMAG-Asia (India, Pakistan, Indonesia with Australia and USA), Burkina Faso, Brazil. Most of those programmes are targeted towards training of agricultural

[2] Hansen, J.W. 2002. Realizing the potential benefits of climate prediction to agriculture: issues, approaches, challenges. Agricultural Systems 74: 309–330.

development and food security professionals in the use of advanced seasonal forecast products for their local situations.

Another important means of communication for seasonal forecasts are the Regional Climate Outlook Forums (COFs). The COFs were initiated by the National Oceanic and Atmospheric Administration (NOAA) in the United States and provide seasonal forecasts. The expected rainfall amounts are based on climate analysis, assessment and data synthesis by various regional forecasting groups. The aim is to arrive at a consensus regional forecast. Not only meteorologists participate in the international framework, but also policymakers and decision-makers are involved.

2.3 Experience from Extension Services: Key Lessons

It is likely that the most effective use of climate information by farmers is reached when the information is provided through existing information channels that farmers are already familiar with. Extension services and staff that have good contacts with farmers can play a key role in the dissemination of forecasts and agricultural advices. One of the most important issues is the timely provision of relevant seasonal information, preferably in combination with management options. Moreover, it is all about the way the information is provided to the different user groups (arable crop farmers, livestock farmers, seed suppliers, etc.). The information needs to be clear and targeted to the specific user groups. The use of seasonal forecasts depends on the users' perceptions of climate variability and how they respond in their agricultural management decisions. The values of seasonal forecasting is largely dependent on the identification of mitigation options and the ability to adopt alternative management practices by the different stakeholders. Many barriers to effective use of the climate information can be overcome when a holistic approach is used that engages all relevant stakeholders in the information generation and dissemination processes.

There are three key issues related to communication:

(a) The information needs to be provided in the appropriate (local) language, should be clearly understandable, and should contain the correct terminology that can assist management decisions for the different stakeholder groups.

(b) Lack of awareness and training of both stakeholders and providers is currently a weakness and needs improvement through specific project, Climate Field Schools, etc.

(c) Spatial and temporal scales of forecasts. The forecast should be made location-specific, meaning that the provided information is relevant for a specific agro-ecological zone instead of an entire country. In terms of temporal scale, the seasonal forecast provides information about rainfall, but not about distribution. Monthly forecasts provide probabilities of rainfall amounts but are too general, while decadal forecasts provide much more detailed information about distribution, but no daily rainfall amounts.

Often the forecast information is too general. For instance the COFs categories of below-normal, normal, and above-normal are considered of little value for agricultural decision making by farmers and extension staff. Determining the level of acceptability of risk for particular negative outcomes is the key issue.

The Climate Field School concept: settling the context for effective communication

Climate Fields Schools (CFSs) are used to increase farmers' knowledge of climate and better prepare them for extreme weather conditions that affect their agricultural activities. In addition, the CFSs are used to teach farmers on climate observations and how to interpret them so that the information can be used for improved decision making in their agricultural management. It is important that farmers become convinced that climate forecast information will be beneficial and can assist in better resilience of their farming activities to extreme climate events. The CFSs are conducting interactive discussions on climate between farmers and a facilitator. The training consists of three basic aspects:

(a) Basic concepts of climate prediction (probability concept, terminology used in climate prediction, and so on), climate forecast products, and explanation of seasonal forecasts on shifting probabilities for crop yields, marketing trends, likely pest outbreaks, and so forth.
(b) The use of historical agriculture data (such as drought/flood data, planting data, frost, harvesting data and agriculture production data) to assess the impact of climate variability/extreme events on agriculture, and simple water balance analysis, technology for harvesting rain, and so on.
(c) The use of climate forecast information for setting up a cropping strategy (cropping patterns, crop rotation, intercropping, and so forth).

The necessity of training the trainers

The way seasonal forecasts are communicated is a key issue in the uptake and behavioural changes of farmers. Most scientists agree that this communication is best facilitated by extension staff that is working in a targeted location. However, not many extension agents have sufficient knowledge of climate and its variability. This lack of knowledge is seriously hampering the translation of a seasonal forecast into operational farming advices for a range of crops. A seasonal forecast should be provided in probabilistic terms, but this is a difficult concept, as probabilities of dry conditions, normal conditions or wet conditions are not easy understood and used for a farm management decision. If deterministic forecasts are being made these may turn out to be 'correct' or 'wrong'. In the latter case this can be very damaging and will lead to distrust in the potential of seasonal forecasts.

Another problem is that in many countries, especially in developing countries, the extension services budgets are heavily cut. Often the extension services have no means of transport, are under staffed, and those who work receive minimal wages. This leads to a lack of motivation and absenteeism, and in many cases the farming communities are not reached by extension agents. Hence there is an important role for WMO to collaborate with other partners (NMHS, NOAA, RISA, SECC, etc.) to promote climate information and to develop training programmes for extension agents, regional journalists and information users. The focus of those training programmes should be on how to use climate information and forecasts for the optimization of agricultural production and reduce risks of the agricultural sector.

Off-farm planning and decision-making

So far, there are not many good examples of resource-poor farmers in developing countries that actively use seasonal forecasts in their on-farm decisions. But, apart from farmers, a whole range of potential users of climate services exists. These agricultural users or stakeholders include:

(a) Information providers;

(b) Owners and suppliers of inputs (seeds, fertilizers);

(c) Buyers and market intermediaries;

(d) Sources and developers of technology;

(e) Financiers of technology transfer;

(f) Local, regional and national governments.

Few studies have attempted to involve relevant actors sufficiently, such as suppliers of agricultural inputs or credit, to exploit the climate information for more profitable and sustainable agricultural practices. Including these off-farm stakeholders in the process of forecast use is an area that should be further developed.

Linking the decision-making calendar to the agro-climatic calendar: seasonality of climate, practices and decision-making inputs

Pulwarty and Melis (2001)[3] introduced the decision-making calendar. This calendar is intended to make the flow of required on-farm decisions clear and to match the decision calendar with the agro-climatic calendar. Hence, it intends to make clear what type of information is needed at which moment in time. The decision calendar is a joint product of farmers, resource providers (seed companies, fertilizer companies, credit facilitators, etc.) and climate information providers. It is a means of discussing and evaluating the timings of information and facilities to generate certain outcomes. It helps to develop specific climate information products needed at different moments in the decision processes of agricultural production for different stakeholders.

2.4 Conclusions

Only a few studies exist that used a holistic approach to evaluate the formation, adoption, and impact of seasonal forecasts for improved agricultural production. Most examples described in the literature recommend on the development and use of climate information, but hardly any examples exist that provide actual testing of the added values of forecasts information for agriculture. Instead, many articles exist that make recommendations for better forecast products and how these products should be communicated. Fischoff (2001)[4] and Pulwarty and Melis (2001) describe the actions required to enhance the acceptability of information and the context in which this information is going to be used.

Before making forecasts:

(a) Meet with recipients or representatives to determine which measures they would find most useful.

[3] Pulwarty, R.S. and T. Melis. 2001. Climate extremes and adaptive management on the Colorado River. Journal of Environmental Management 63: 307–324.

[4] Fischoff, B. 2001. Learning from experience: coping with hindsight, bias and ambiguity. In: Principles of Forecasting (J.S. Armstrong, ed.). Norwell, Kluwer Academic Publishers.

(b) Independently analyse the problems that stakeholders face in order to obtain a complementary perspective.

(c) Empirically test formats for communication in order to ensure that stakeholders understand the information as intended.

(d) Seek users' explicit agreement on appropriate formats.

(e) Develop decision calendars cooperatively with stakeholders to determine key entry points for different kinds of information.

While making forecasts:

(a) Make the nature of links to decision calendars and the forecast as explicit as possible, including alternate possible outcomes.

(b) Document the assumptions underlying forecasts, including how changes in seasonal development would change the forecast (how the forecast is verifying).

When evaluating the use of forecasts:

(a) Do post-season farmer workshops.

(b) Review what was predicted and what assumptions were made.

(c) Construct explanations not only for what actually happened, but what could have happened as a way of retrieving uncertainties at the time of predictions.

(d) Evaluate what new information was learned about the process producing the event predicted as well as the event itself.

3. Case studies of agricultural decision-support and extension services

In 2005, from 11 to 13 May, a conference was held at WMO, Geneva, to discuss the progress made on climate prediction for agriculture. This 'International Workshop on Climate Prediction and Agriculture – Advances and Challenges' reviewed advances in the use of seasonal forecast for agricultural purposes, and identified the main challenges in the operational use of climate information in agriculture. Prior to the international workshop a 'Synthesis Workshop of the Advanced Institute on Climatic variability and Food Security' was held from 9 to 10 May 2005, also at WMO in Geneva. During this workshop the results of the Packard Foundation funded project on climate variability and food security were presented. The papers presented during the two workshops at WMO were published in the book 'Climate Prediction and Agriculture: Advances and Challenges' (Sivakumar and Hansen, 2007)[5].

Overall, the presented papers showed that the skill of seasonal forecasting had improved in the years before 2005, and that there was a huge potential for using climate information in agricultural decision making, but the actual use of the probabilistic forecasts in case studies was quite limited. This was highlighted by Anderson (2007)[6] who was asked to react to the presented papers and draw the main lessons learned and propose future challenges of climate prediction for agriculture. According to Anderson, a key item in the research and development of climate prediction in agriculture should be the assessment of *ex ante* and *ex post* climate forecast value. Most of the papers presented in the two workshops did not touch upon this issue, but merely addressed climate modelling, downscaling, forecast production, forecast skill, etc. Many of the presented studies actually described what information can be generated an how it could be used, but the actual testing of the climate predictions in agriculture largely lack in the published studies.

Moreover, Anderson questioned if the investments in climate forecasting have resulted in similar returns as investments in more conventional agricultural research on crop varieties, nutrient management, etc. For example, Cui et al. (2018)[7] reported major improvements in agricultural production in China, but the use of climate information is not mentioned as one of the measures that underlies the better agricultural output. Instead, the reported improvements are the result of a comprehensive decision-support integrated soil–crop system management programme for growing maize, rice and wheat across China's vast agro-ecological zones. Hence, the successful programme is based on conventional soil, crop and land management information and advice, targeted to specific crops in different agro-ecological zones. The only climate factor involved here is the definition of agro-ecological zones.

The smallholder farmers of Africa are probably the ones who most need accurate weather information to base agricultural decisions on. A few studies have shown the potential for

[5] Sivakumar, M.V.K. and J. Hansen. 2007. Climate Prediction and Agriculture: Advances and Challenges. Springer, Berlin, Germany.

[6] Anderson, J.R. 2007. Climate prediction and agriculture : lessons learned and future challenges from an agricultural development perspective. P. 279-283 In Sivakumar, M.V.K. and J. Hansen. 2007. Climate Prediction and Agriculture: Advances and Challenges. Springer, Berlin, Germany.

[7] Cui, Z. et al., 2018. Pursuing sustainable productivity with millions of smallholder farmers. Nature 55: 363-366.

seasonal forecasts to improve agricultural productivity and socio-economic conditions in Africa. For instance, farmers in Kenya tested the added value of including meteorological information (seasonal, monthly and weekly weather updates) in decision-making processes (Aura et al., 2015)[8]. Inclusion of this information in farm management resulted in better productivity and improved the return on investment. Moreover, in a participatory study in Senegal, 75% of the farmers adapted crop cultivation strategies when they received seasonal weather information, which resulted in better yields, especially in the relatively wet years (Roudier et al., 2014)[9].

Despite some efforts to provide seasonal forecasts, so far the use of this information in Africa has been minimal[8]. Important reasons are:

1) the variable accuracy of the current forecasts through the Regional Climate Outlook Forums (Chidzambwa and Mason, 2008)[10];

2) the lack of downscaling and translation of the forecasts to location-specific agricultural advice to farmers (Hansen et al., 2011)[11];

3) the failure to guarantee timely and adequate provision of forecast information to farmers (Hansen et al., 2011)[11];

4) the mismatch between the information farmers require and that provided by the National Meteorological Services (Meinke et al., 2006)[12].

In this chapter a number of case studies from outside Africa are presented where agro-meteorological information and prediction is used for decision making in agriculture. It is by no mean complete, and relies on the case studies as described by ET 3.2 members only.

[8] Aura S., S. Kahuha, B. Chanzu., N.J. Muthama and F.K. Karanja, 2015. Making Meteorological Services more Beneficial to Farmers. WMO Bulletin 64(1).
[9] Roudier, P., B. Muller, P. d'Aquino, C. Roncoli, M.A. Soumaré, L. Batté and B. Sultan. 2014. The role of climate forecasts in smallholder agriculture: Lessons from participatory research in two communities in Senegal. Climate Risk Management 2: 42–55.
[10] Chidzambwa, S. and S.J. Mason, 2008. Report of the evaluation of Regional Climate Outlook Forecasts for Africa during the period 1997 to 2007. ACMAD Technical Report, 30.
[11] Hansen, J.W., S.J. Mason, L. Sun and A. Tall, 2011. Review of seasonal climate forecasting in Sub-Saharan Africa. Exploratory Agriculture 47: 205-240.
[12] Meinke, H., R. Nelson, P. Kokic, R. Stone, R. Selvaraju and W. Baethgen, 2006. Actionable climate knowledge: from analysis to synthesis. Climate Research 33: 101–110.

3.1 China

By: Yanling Song

3.1.1 Agricultural services for drought mitigation

As one of the most serious natural disasters in the world, drought has received much attention by scientists. The north of China, which is a fast economic developing region, is facing serious problems of water shortage. The main reason for the lack of water resources is the precipitation decrease since the mid and late 1970s. Furthermore, the current global warming enhances the problem of water shortage in this region. For example, 0.76 million ha of crop land were influenced by droughts and 0.45 million people had not enough water to live just in Henan province in spring 2007. So, a better understanding about the drought impacts on agriculture can help to realize food-security in north China. Agricultural decision support services for drought mitigation are important in China to assist agricultural production. The following provides examples of agricultural decision support in different provinces/regions of China.

Winter wheat services on drought

Winter wheat is one of China's most important staple food crops. It's growth and yields are strongly influenced by weather, especially drought. Shandong, Hebei, Beijing, Tianjin, Shanxi and Henan provinces are the major winter wheat-growing region on the North China Plain. The total arable area is about 30 million hectares, of which 50% is used for winter wheat.

The climate of the region is variable, and includes temperate, semi-humid and monsoon-controlled climatic zones. The annual mean temperature varies from 10 to 15°C. Summers are rainy and hot (monthly mean temperatures range from 22 to 28°C), whereas winters are dry and cold (monthly mean temperatures range from -10 to 1°C). The total annual precipitation generally ranges from 400 to 800 mm depending on circulation patterns and topographic features. Furthermore, strong East Asian monsoons often bring colder winters, while droughts are common in spring time.

Figure 3.1: Mulching with straw to conserve soil moisture for a young winter wheat crop.

Previously in Henan province, droughts occurred frequently, which affected the growth and yields of winter wheat. The local farmers have been advised to covered the soil surface with straw of the previous year winter wheat crop (Fig. 3.1). This mulching increases the soil moisture availability by reducing soil evaporation, which results in better growth of the wheat.

Apple tree services on drought

In Shaanxi province of China, the area with apple trees amounts to 666.7 thousand hectare. The production of apple is about 10 million tons per year, which amounts to 12.8% of the total annual production of the world. The annual precipitation in the north of Shaanxi province is the range of 200-400 mm, and droughts happen frequently. As a result, the production of apple is strongly influenced by drought. Local farmers have been taught a new water harvesting method to mitigate the impacts of drought (Fig. 3.2). Farmers cover the ground around the apple tree trunk using plastic film. Due to the natural slope of the field and the plastic cover the precipitation is collected and channelled to the roots of the apple trees. Through this new method, more water is conserved and made available to the apple trees, which helps to overcome the negative impacts of drought. As a result, the production of apple is increased using this new water harvesting method.

Figure 3.2: Water harvesting method in an apple tree field. The plastic is put on the soil to harvest rainfall and channel the water to the tree roots.

3.1.2 Agriculture services on low temperatures in China

At present, 40% of the Earth's land surface is managed for cropland and pasture. Being a large developing country, China has a total population about 1.3 billion with 73% of them pursuing agriculture. The crop land area covered 1.3 billion ha in 2009. About 20% of the global population lives in China and they are supported only by 7% of the world's cultivated land. Northeast China is one of the most important marketable grain producing areas in China, and staple crop production amounts to 84 million tons per year, which is 15.8% of the total production of China. Rice is a staple crop in northeast China, which has high yields and superior quality.

The inter-annual, monthly and daily distributions of climate variables (e.g., temperature, radiation, precipitation, water vapour pressure in the air and wind speed) affect a number of physical, chemical and biological processes that drive the productivity of agriculture. The latitudinal distribution of crop is a function of the current climatic and atmospheric conditions, as well as of photoperiod. Short-term natural extremes, such as low temperature droughts and floods all have important effects on crop. Low temperatures form a main climatic disaster which influences the growth of rice. This is especially the case in spring in north-eastern China.

Changed rice varieties to overcome low temperatures

Wuchang, located in northeast China, has an annual mean temperature of 2 to 7°C, summer is rainy and warm (monthly mean temperatures range from 18 to 25°C), whereas winter is dry and cold (monthly mean temperatures range from -10 to 1°C). The total annual precipitation generally ranges from 400 to 1000 mm depending on circulation patterns and topographic features.

In Wuchang, the annual mean temperature showed an increasing trend with 2.5°C from 1961 to 2009 due to the global warming. The decadal mean temperatures increased from 3.4°C in the 60's to 4.9°C in the 1990's, and 5.3°C during 2001-2009. These results showed clearly that the annual mean temperature increased apparently from the 1980's. At the same time, the accumulated temperature (>10°C) also showed the increasing trends by 84.9℃ per 10 year. For example, the accumulated temperature was only 2848.6°C in the 1960's, and it increased since the 1980's The accumulated temperature was 2933.2°C in the 1980's and 3026.5°C in the 1990's, respectively. Since then it has amounted to 3155.8°C during 2001-2009, which is an increase of 307.2°C compared with the 1960's.

Farmers have been advised to plant different rice varieties to adapt to climate change. For example, the rice varieties were changed nine times from 1981 to 2009, which is about one rice variety change every four years (Table 3.1). The rice yield in Wuchang has increased. In the 1980's, the mean yield of rice was 5087.3 kg/ha, and in the 1990's, the mean rice yield increased to 7616.4 kg/ha, while it amounted to 9072.2 kg/ha in 2000, increasing by 78.3% compared to the 1980's. In total, the rice yield was observed to increase 2095 kg/ha for every 10 years in Wuchang station due to the new rice varieties mainly.

Table 3.1: The rice variety changes to cope with climate change in Wuchang from 1981 to 2009.

Year	Varieties of rice	Year	Varieties of rice	Year	Varieties of rice
1981	XX14-1	1991	985-5	2001	938-8
1982	XX14-1	1992	DL5-6	2002	938-8
1983	XX14-1	1993	DL5-6	2003	938-8
1984	XX14-1	1994	DL5-6	2004	938-8
1985	XX14-1	1995	DL5-6	2005	938-8
1986	XB-2	1996	DL5-6	2006	938-8
1987	ZM-3	1997	C19	2007	DXC-9
1988	C19-4	1998	T35-7	2008	DXC-9
1989	C19-4	1999	T35-7	2009	DXC-9
1990	C19-4	2000	T35-7		

Rice seeding in green house services on low temperature

In northeast China, the annual mean temperature was only 0-8°C, and the mean temperature was only 5-15°C in May, when the rice would be seeded. Often, the young seedlings were affected by low temperatures, and the growth of the young seedling would be reduced. Local farmers were stimulated to solve the low temperature problems. They have built green house for rice seeding. Inside the green house, the temperature is usually higher than outside, and when the outside temperature drops, the young seedlings survive better because they get more thermal energy and time to grow.

Figure 3.3: Rice seedlings inside a greenhouse in northeast China.

3.2 Australia

By: Geert Sterk

3.2.1 Introduction

Agriculture is one of the main economic pillars in Australia. The agricultural sector employs 307,000 people and contributes 3% to the Australian GDP. When the complete agricultural supply chain, including food and fiber industries is considered, there are over 1.6 million jobs, and the GDP contribution is 12% (NFF, 2012)[13].

Agriculture in Australia is a mix of irrigated and dryland crop farming, and livestock production. The country has three main agricultural zones (Shaw, 1984)[14]:

1. the high rainfall zone of Tasmania and a narrow coastal zone used mainly for dairy and beef production;
2. the wheat-sheep zone with a mixture of winter crops and sheep + cattle grazing, and
3. the low-rainfall pastoral zone with large scale pastoral activities such as grazing of cattle and sheep.

Climate change may have a profound influence on Australian agriculture. Benefits may arise from longer growing seasons in a warmer climate and increasing atmospheric CO2 concentrations, but these benefits may become unsustainable given the more extreme projections of global warming. Furthermore, climate change will cause decreased precipitation over much of Australia and this will increase pressure on the existing challenges to water availability for agriculture (Preston and Jones, 2006)[15].

The unreliability of rainfall during most years is one of the major risk factors in Australia's agricultural business. The drought that started in 2012, following the last La Niña episode, is a real burden for many farms in drought prone areas. The Australian Bureau of Meteorology (BoM) believes that these drought conditions are not only caused by the strong 2015 El Niño, but could be related to other changes in the climate system. According to BoM researchers, long-term drying trends over southern Australia cannot be explained by natural variability alone.

Farm management decisions largely depend on available and expected water resources. If the next rainy season is expected to have above average rainfall, a farmer may want to sow more crop, or keep most of his entire herd because the amount of grazing resources is expected to be good. On the other hand, a below average rainfall during the season may cause farmers to avoid risk and or sow a more drought-prone crop or sell part of their livestock in the market when prices are relatively high. Accurate predictions of seasonal, sub-seasonal and even weekly rainfall amounts can greatly assist in taking agricultural decisions.

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[13] NFF, 2012. NFF Farm Facts 2012. National Farmers' Federation, Canberra, Australia.

[14] Shaw, J.H., 1984. Collins Australian Encyclopedia, William Collins Pty Ltd., Sydney, Australia.

[15] Preston, B.L. and R.N. Jones. 2006. Climate Change Impacts on Australia and the Benefits of Early Action to Reduce Global Greenhouse Gas Emissions. CSIRO Marine and Atmospheric Research. Canberra, Australia.

3.2.2 Agro-meteorological information services

The BoM is providing agro-meteorological information for the agricultural business. On their website (http://www.bom.gov.au/) there is a special section 'Water and the Land; For Agriculture and Natural Resources Management' which provides an integrated suite of information for people involved in primary production, natural resource management, industry, trade and commerce. It provides different services and gives information on rainfall, cloud, temperature, wind, pressure, El Niño and La Niña, humidity, evaporation and sunshine. The information includes long-term outlooks, shorter-term forecasts, latest weather, recent weather, averages and long-term trends.

Availability of agro-meteorological information is a prerequisite for good agricultural decision support, but the information is not always used at its maximum benefit. In Australia the Managing Climate Variability R&D Programme (http://www.managingclimate.gov.au/) has been working with farmers and natural resource managers to manage Australia's variable and changing climate for over 20 years. The programme tries to improve forecasts, provide tools and information to manage climate risk, and help farmers with strategies to manage climate risks. One of the programme's main decision support tools is the 'Climate Kelpie' website (http://www.climatekelpie.com.au/).

3.2.3 Climate Kelpie

Climate Kelpie is a 'one-stop shop' for climate risk management information and tools. It was designed for Australian farmers and farm advisors. It provides tools and information about climate and can assist to make agricultural decisions. Every month new links to credible and relevant tools and information are added. Much of the information comes from the BoM, but also links to the UK Met Office and MetEye forecasts are available. Farmers can find information on:

(a) rainfall forecasts for their region

(b) expert interpretations of the seasonal forecasts for their region

(c) decision-support tools to help manage farms in a changing climate

(d) what drives the climate and weather in their region

(e) information about the changing Australian climate

The website offers links to 38 decision support tools for a range of agricultural commodities and agronomic processes (yield forecasts, disease control, etc.).

Apart from the Climate Kelpie website, the Managing Climate Variability Programme has initiated a Climate Champion programme in which farmers are helped to manage climate risk. Early 2016, 20 farmers participated in the programme. They receive the best climate tools, products, practices and seasonal outlooks, and an understanding of how they might use the information and tools in their farm business. The programme stimulates interaction between farmers and researchers, which helps to streamline research in climate risk and adaptation strategies. These discussions also influence the way in which research findings are communicated to farmers.

Box 1: Selected statements of Australian farmers participating in the Climate Champion programme of the Managing Climate Variability Programme (http://www.climatekelpie.com.au/)

Andrew Watson - Boggabri, northern New South Wales; Irrigated and dryland cotton, grains.

'*The biggest decision we have to make each year is how much cotton we are going to plant. That's based around water; namely, how much water I have available for irrigation. When we have an idea of that, I can make planting, harvesting, irrigation and other operational decisions well in advance.'*

'We use seasonal forecasts for strategic decision-making, like setting up long-term crop rotations, or property purchase or sale. Monthly forecasting informs our tactical decision-making process, like ordering fertilizer or seed so we have it on-farm if a predicted weather event occurs. Weekly forecasting helps us with operational decision-making, like when to spread fertilizer, or deciding to harvest grain slightly early with a high moisture content and being prepared to dry it rather than risk quality downgrades from a rain event.'

'We know that forecasts are probabilistic, so we don't want to plant 100 per cent of our irrigated land to cotton because we want to spread our risk.'

Susan Carn - Quorn, Flinders Ranges, South Australia; Merino sheep, wheat and barley.

'*The Bureau of Meteorology has an experimental forecasting tool—POAMA—and I think other dynamical climate models are well worth looking at. I also look at 3-month seasonal forecasts produced by Japan and Korea. These forecasts use dynamical climate models to produce forecast maps for the world and explain what climate drivers are responsible for the possible outcomes.'*

'I've found that seasonal forecasts and climate drivers like the Southern Oscillation Index and Indian Ocean Dipole are important tools to help us in our decision-making. Over the last 5 years I have had great success in using seasonal forecast data in my decision-making for both in cropping and sheep enterprises. For example, in 2010 the forecasts agreed we would have a dry winter, wet spring and a very wet harvest. Our decision was to sow conservatively and be ready to harvest as quickly as possible. As a result we had no grain downgraded. So by sowing less, we made more!'

'We also brought our lambing time forward as forecasts were for the La Niña to last well into autumn 2011, followed by another dry winter. Lambing around here is traditionally timed for winter, but by changing to late autumn our lambs were born before paddock feed diminished. The result was over 100% lambing rates and very big lambs at sale time—a very profitable decision.'

Colin Dunne - Duaringa, Central Queensland; Sorghum, corn, mungbeans, chickpeas, wheat, cattle

'I enjoy reading the small climate section in the Queensland Country Life, because I get it weekly and it's easy to read. There are many farmers who don't use the internet much, so climate and weather information in the newspapers is great.'

'I do go online occasionally to seek that information out.'

'I'm sure we are improving long-term forecasting - certainly the 7-day forecast and multi-week outlook is getting better. Over the past couple of years, the predictions of rainfall have been pretty close, and that's why I haven't raced in with a summer crop.'

'It would also help us with the cattle - if a season was to stay dry, I'd start feeding them protein in August. But if you knew it was going to rain, I'd let them hold over.'

A special section on the Climate Kelpie website is devoted to cases studies of the current and previously participating farmers (http://www.climatekelpie.com.au/farmers-managing-risk/farmer-case-studies). For each farmer a short description is given of his/her enterprise and the way agro-meteorology information is used for agricultural decision making. Some selected statements have been copied from the Climate Kelpie website and shown in Box 1.

These examples show that farmers actively look at seasonal and sub-seasonal precipitation forecasts, and use this information for their farm management decisions. A few farmers (Mark and Andrea Hannemann; Peter Holding) have mentioned the use of decision support apps, but do not give details about their experiences. It also remains unclear how many of the farmers that did not participate in the Climate Champion programme actually use the seasonal and sub-seasonal forecasts for agricultural decision making, but it would be highly interesting to evaluate this.

3.3 USA

By: Clyde Fraisse.

3.3.1 Introduction

According to the Köppen climate classification, the climate of Florida is classified as humid subtropical with hot summers (Cfa) (Peel et al., 2007)[16]. Mean average temperatures during Florida's coldest month (January), range from 10-12°C in the north to 19-21°C in the south. During the hottest month (July but in some places August) average temperatures are almost the same throughout the state ranging between 27° and 28°C. Large water bodies such as the Atlantic Ocean and the Gulf of Mexico are major modifiers of the state's temperature during all seasons but particularly during the winter when temperatures in nearby locations will remain milder than inland areas (Winsberg, 2003)[17].

Although Florida ranks second in the country in the production of strawberry, producing between 10 and 15 percent of the total U.S. crop, mild winters allow Florida to produce virtually 100 percent of the domestically produced winter strawberry crop (Mossler, 2012)[18]. Strawberries are one of the most valuable crops in Florida. In 2012, about 4,000 ha were devoted to strawberries with an estimated return to the grower approaching to $250 million (USDA, 2013)[19]. However, the high value of the strawberry crop often compels growers to protect their fruit by applying fungicides preventively, mainly for control of Anthracnose and Botrytis fruit rots. In Florida, fungicides are traditionally applied weekly from December through March (Legard et al., 2005)[20].

Anthracnose fruit rot (AFR), caused by *Colletotrichum acutatum* (Smith, 1998)[21], and Botrytis fruit rot (BFR), caused by *Botrytis cinerea* (Sutton, 1998)[22], are the most important diseases for production of annual strawberries in Central Florida and worldwide (Pavan et al., 2011)[23]. Anthracnose is a serious disease that affects the fruit in addition to flowers and petioles. It is favoured by warm temperatures (>18°C) and wet weather. Losses due to the Anthracnose can exceed 50% when conditions favour disease development, even in well-managed fields (Turechek et al., 2006)[24]. Botrytis fruit rot is an important pre-harvest and postharvest

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[16] Peel, M.C., B.L. Finlayson and T.A. McMahon. 2007. Updated world map of the Köppen–Geiger climate classification. Hydrology and Earth System Sciences 11: 1633–1644.

[17] Winsberg, M.D. 2003. Florida Weather. 2nd ed. University Press of Florida. Gainesville, FL, USA.

[18] Mossler, R. 2012. Florida Crop/Pest Management Profiles: Strawberry. University of Florida IFAS Extension EDIS circular CIR1239.

[19] USDA. 2013. U.S. strawberry harvested acreage, yield per acre, and production,13 States, 1970-2012. http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1381. Accessed July, 2016.

[20] Legard, D.E., S.J. MacKenzie, J.C. Mertely, C.K. Chandler and N.A. Peres. 2005. Development of a reduced use fungicide program for control of Botrytis fruit rot on annual winter strawberry. Plant Disease 89: 1353–1358.

[21] Smith, B. 1998. Anthracnose fruit rot (black spot). P. 31–33 in Compendium of Strawberry Diseases (second ed). APS Press, St. Paul, MN, USA.

[22] Sutton, J., 1998. Botrytis fruit rot (gray mold) and blossom blight. P. 28–31 in Compendium of Strawberry Diseases (2nd ed). APS Press, St. Paul, MN, USA.

[23] Pavan, W., C.W. Fraisse and N.A. Peres. 2011. Development of a web-based disease forecasting system for strawberries. Computers and Electronics in Agriculture 75: 169-175.

[24] Turechek, W., N. Peres and N. Werner. 2006. Pre- and post-infection activity of pyraclostrobin for control of anthracnose fruit rot of strawberry caused by colletotrichum acutatum. Plant Disease 90: 862–868.

disease of strawberry, infecting the floral parts, including stamens and petals. The conidia are wind- and splash-dispersed, requiring free moisture (>4 h of leaf wetness) and cool temperatures (15–22°C) to infect and sporulate. The disease can be controlled by a combination of cultural practices and chemical methods, but there is no completely resistant strawberry cultivar (Legard et al., 2005)[20].

The high financial and environmental costs of applying fungicides preventively enticed a team of researchers at the University of Florida to develop a web-based disease warning system to help growers to eliminate unnecessary pesticide applications and reduce production costs. Rational fungicide spraying, as guided by disease warning systems, can provide benefits by reducing production costs, mitigating hazards to the health of farm workers and consumers, and lessening the negative impacts of pesticides on the environment (Gleason et al., 2008)[25].

The Strawberry Advisory System (SAS) (Pavan et al., 2011)[23] was developed to provide strawberry growers with a tool to improve diseases management by helping them to spray only when environmental conditions favour disease development. SAS is part of the AgroClimate (Fraisse et al., 2006)[26] suite of tools that provide extension agents, producers, and natural resource managers in the Southeastern USA with decision aid aimed at reducing risks associated with climate variability.

3.3.2 Strawberry Advisory System

SAS was implemented with well-established design patterns and rules allowing the establishment of standards for eventual AgroClimate expansions. The disease models were implemented using the R statistical analysis software system (http://www.r-project.org), which is a language and environment for statistical computing and graphics generation. Weather observations collected at Florida Automated Weather Network (FAWN) stations and additional weather stations installed in the main strawberry production region of the state are used to drive the system. Short-term weather forecasts obtained from the National Weather Service-National Digital Forecast Database (NWS-NDFD) are also used to predict disease-risk levels for the next 48 hours.

The main SAS web page presents a map with the available stations using different colours to quickly present the presence or absence of conditions favourable for the development of the diseases (Fig. 3.4). The system presents risk levels using three different colours: green (no risk), yellow (moderate risk) and red (high risk). If more specific information is desired, users can select a weather station with a simple click and obtain additional information in a balloon. If a recommendation is required to make a decision, the user can click on the button "Click for recommendation", that expands the balloon presenting a simple questionnaire to guide the decision making process and provide a recommendation. Simulated Botrytis and Anthracnose risk levels are presented in separated tabs and displayed in plots and a tabular

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[25] Gleason, M.L., K.B. Duttweiler, J.C. Batzer, S.E. Taylor, P.C. Sentelhas, J.E.B.A. Monteiro and T.J. Gillespie. 2008. Obtaining weather data for input to crop disease-warning systems: Leaf wetness duration as a case study. Scientia Agricola 65: 76-87.

[26] Fraisse, C.W., N. Breuer, D. Zierden, J. Bellow, J. Paz, V. Cabrera, A.G. Garcia, K. Ingram, U. Hatch, G. Hoogenboom, J. Jones and J. O'Brien. 2006. Agclimate: a climate forecast information system for agricultural risk management in the southeastern USA. Computers and Electronics in Agriculture 53: 13–27.

format (Fig. 3.5). Recent weather data is presented in the “Weather tab” to provide users with the ability to verify weather conditions associated with simulated risk levels. This information may be useful to decision-makers and researchers to assist them in the interpretation and understanding of the weather conditions associated with the diseases.

The system has been operational since the 2009/2010 season. During that season the weather conditions were not favourable for the development of diseases due to the extreme low temperatures in January and February. In general, producers were able to reduce the number of fungicide applications by about half by following the recommendations of the system without affecting disease control and yield. The benefits of using the system are generally emphasized during seasons where conditions are not favourable for disease, such as during La Niña events which normally result in drier conditions in the region. Currently SAS has 105 registered users representing the majority of strawberry growers in the state. They receive warnings via e-mail and/or SMS text messages on mobile phones. Recently we also developed a mobile version of SAS (Fraisse et al., 2016)[27] that is available for download through the official app stores for mobile devices with iOS and Android operating systems. The app is designed to be easy to use, so it contains only the essential functionality available in the web-based SAS.

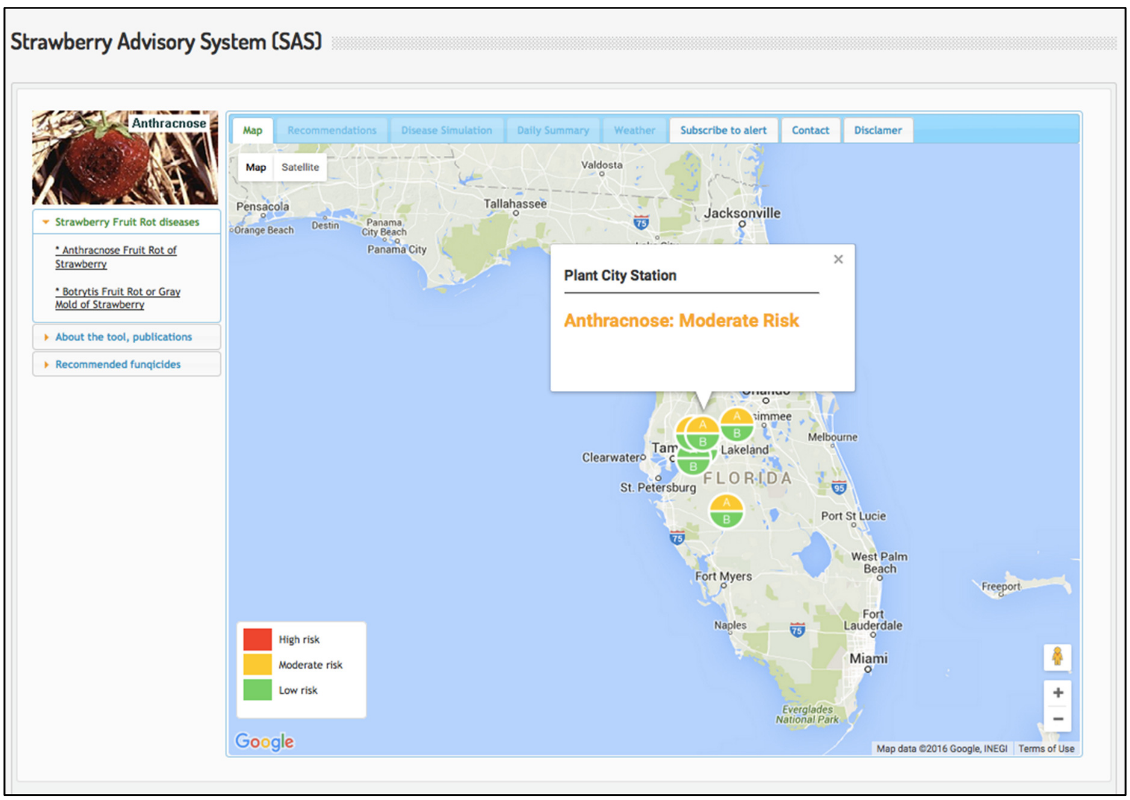

Figure 3.4: The main web page for the Strawberry Advisory System showing the stations located in Florida.

[27] Fraisse, C.W., N. Peres and J. Andreis. 2016. Smart strawberry advisory systems for mobile devices. University of Florida IFAS Extension EDIS circular AE516: http://edis.ifas.ufl.edu/ae516.

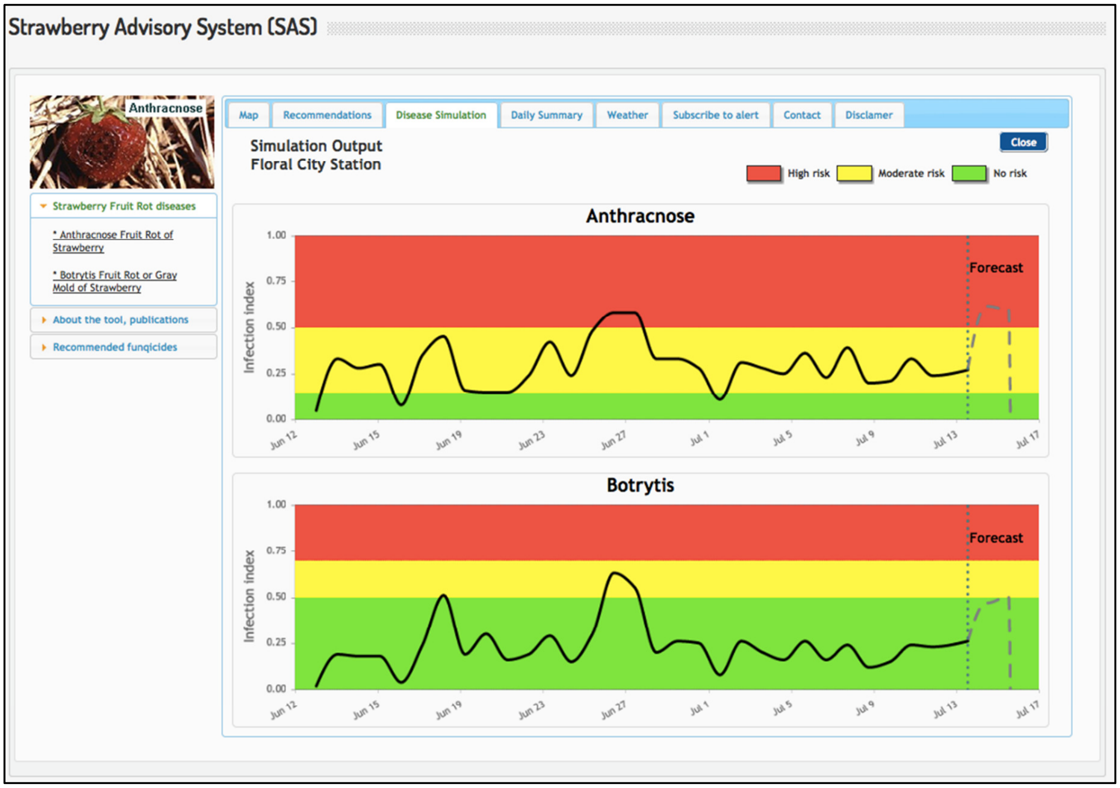

Figure 3.5: Simulated Anthracnose and Botrytis risk for the last 30 days and forecast for the next two days.

3.3.3 Conclusions

The implementation of SAS to monitor and predict the risk of Anthracnose and Botrytis fruit rot on strawberries enabled growers to easily access the information necessary for them to decide about the need for fungicide applications Growers using the system are informed when to apply fungicides. The recommended applications are only provided when conditions are favourable for disease development, thus reducing the number of applications and production costs, without compromising disease control or yields. SAS has been recently expanding to other states in the USA including South Carolina, Virginia, and California. Currently we are investigating the use of model-based leaf wetness estimations (Montone et al., 2016)[28] to allow the simulation of leaf wetness based on gridded weather data that, combined with temperature, will allow the creation of daily disease risk maps, significantly improving the ability of the system to provide information in most strawberry producing areas of the USA.

[28] Montone, V.O., C.W. Fraisse, N. Peres, P.C. Sentelhas, M. Gleason, M. Ellis and G. Schnabel. 2016. Evaluation of leaf wetness duration models for operational use in strawberry disease-warning systems in four US states. International J. of Biometeorology. DOI 10.1007/s00484-016-1165-4.

3.4 Russia

By: Vera Pavlova

3.4.1 Introduction

The history of land use cannot be considered without its adaptation to changing natural and, first and foremost, climate conditions. For Russia with its extreme continental climate and vast territories climate-based land use and agro-technologies are of utmost importance. Arable crop production is very vulnerable to seasonal droughts and heat waves. This dependence on weather conditions makes the country's agricultural output volatile (Liefert, 2002)[29]. As the incidence of heat waves along the grain belt of Russia is projected to increase with global warming (IPCC, 2013)[30], climate change is anticipated to increase the vulnerability of Russian agriculture and its output volatility.

One may take a look at climate-based challenges to Russia's sustainable development with the examples of two years: 2008 as a good year and 2010 as an unusually dry year. In 2008 total yield of arable crops and beans in Russia was 108 mln tons, while in 2010 only 61 mln tons were harvested. Thus climate-based loss in yield due to drought in 2010 was roughly equal to 47 mln tons.

In three years from 2008 to 2010 agro-technology and arable land could not undergo drastic changes. The related output decrease by 40-50 mln tons (or 40-50% out of possible real output) gives an estimation of climate-based challenges that Russia faces at the current level of agro-technology. From 1951 to 2010 droughts that led to 40-50% decrease in arable crops yield in European Russia were witnessed in 1972, 1981 and 2010. Hence frequency of major droughts in European Russia is about 5% and such droughts take place roughly once per two decades.

3.4.2 Agro-meteorological decision support

Russia has a system of operational agro-meteorological and agro-climatic support to agriculture. On federal and regional levels the system includes regular provision with analytical materials and agro-meteorological forecasts, as well as special reports and notes on demand from authorities of the agro-industrial sector.

An Information Forecast System (IFS) was developed for operational units of the Hydro-meteorological Service of RosHydroMet. The main goal of this system is to create an integrated technological chain of automatic generation of operational agro-meteorological products. These agro-meteorological products provide generalized analytical information on present and expected agro-meteorological conditions aimed for a wide range of users, including farmers, and acquired as a result of processing of data received from hydro-meteorological stations.

[29] Liefert, W. 2002. Comparative (Dis?)Advantage in Russian Agriculture. American Journal of Agricultural Economics 84: 762-767.

[30] IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

In operational practice each Centre of Hydro-meteorology and Environmental Monitoring (CHEM) publishes on its website weekly reports on agro-meteorological conditions and dangerous events in the territory of the centre's responsibility. The following provides a few examples of such agrometeorological support.

1. Volga region Office on Hydrometeorology and Environmental Monitoring (OHEM):

http://www.pogoda-sv.ru/monitoring/agrometeo_danger

Weekly agro-meteorological information sheet on dangerous events (22 March 2016)

According to data acquired from meteorological stations Klyavino and Kinel-Tcherkassy for seventy days (mid-January till mid-March 2016) snow cover depth was within 32-62 cm, depth of soil freezing was 7-27 cm. minimal temperature at the depth of tilling zone for winter crops constituted 0.0 to -1.0°C. Combination of these factors presents conditions for asphyxiation of winter crops.

2. Stavropol region CHEM

http://www.meteo.stv.ru/agro.shtml

Information sheet for agricultural producers and farmers:

Stavropol region CHEM and its network offices (meteorological stations and posts) is charged by the government to conduct observations and exercise monitoring of hydro-meteorological events, provide fact sheets on dangerous hydro-meteorological events witnessed in the territory and leading to damages. In the case when there are no observation nodes of hydro-meteorological service in certain sub-regions dangerous and damaging events can be confirmed via on-site studies with participation of CHEM specialists. Hydro-meteorological events in the warm time of the year (hail, shower, squall wind) are of local character, thus fact sheets are provided only when a document of study is in place. In case of a dangerous hydro-meteorological event that led to damages, agricultural producers and farmers should inform the CHEM on the occurrence within three-day periods. Insurance companies need to inform their clients on deadlines and rules of acquisition of fact sheets on dangerous events. Therefore witnessed meteorological and agro-meteorological parameters are a necessary element in receiving insurance in case of dangerous hydro-meteorological events.

Agro-meteorological conditions of growth and development of arable crops (21 April 2016)

Agro-meteorological conditions of growth and development of winter crops in mid-April were favourable due to a sufficient supply of heat and water. Plantings of winter crops continued to develop stems. Water supply of the plantings in the majority of the region was estimated as adequate. In western and north-western sub-regions water supply was good or optimal. In certain areas, namely in the Petrovsky, Blagodarnensky and Georgiyevsky sub-regions, water supply was insufficient. The state of the winter crops as of 20 April was in general good or satisfactory.

3. CHEM of Bashkir republic.

http://www.meteorb.ru/agrometeorologiya/memo-to-farmers

The Bashkir republic is suffering more frequent dangerous agrometeorological events, and sub-regional offices as well as agricultural producers more often address meteorological stations for information on crop failure. A meteorological station has to confirm or deny the fact of arable crop failure. In case of crop failures, a specialist of the meteorological station signs the act of crop study and stamps the document with a seal of the meteorological station. The station is responsible for reliability of this information. Occasional studies are conducted in case of weather events disadvantageous for agriculture (showers, hail, dust storms, droughts, major frosts, etc.).

In all the fields subject to plantings studies the following parameters are noted:

- Visual evaluation of state;
- Assessment of impurities;
- Extent of damage done to plants by pests, diseases and unfavourable meteorological events;
- Phase of development;
- Area of damaged plantings;
- Plant height;
- Plant population.

The aim of study is to acquire the fullest possible information on character, extent and scale of damage to plants from unfavourable meteorological events or the scale of an unfavourable meteorological event and its intensity (e.g. for a drought).

4. The Ministry of Agriculture of Russia - criteria for considering territories disadvantageous for agriculture.

http://base.garant.ru/70853938/#friend

Six separate parameters and one integral parameter are used to evaluate regions on the scale of disadvantageous territories for agriculture. For example, the system of separate parameters includes climatic character of rural areas. The list of regions will be used in carrying out the support measures of agricultural producers in accordance with the World Trade Organisation norms.

Criteria for considering territories as disadvantageous for agriculture are based on estimates of the areas prone to major droughts or flooding. Agro-meteorological parameters are calculated based on data of hydro-meteorological observations for a period of at least two decades:

a) probability of major droughts (Hydro-Thermal Coefficient [HTC] of water supply equals or is less than 0.6) – 50% of territory and more;

b) probability of excessive water supply during the harvesting period (HTC of water supply equals or exceeds 2.0) – 30% of territory or more.

For the May-August and September-October periods the National Russian Institute of Agricultural Meteorology (NRIAM; http://www.cxm.obninsk.ru) calculates the HTC for the whole arable area of Russia based on data received from 770 hydro-meteorological stations.

Thus agricultural producers and farmers are able to use the information on evaluation of agro-meteorological conditions in their area via addressing websites of regional CHEMs. Development of the agricultural insurance system leads to more users of hydro-meteorological information. It is possible that the number of farmers using the information provided by RosHydroMet is increasing every year, yet estimating the exact figure seems to be impossible.

Vitaly Andreev, agricultural insurance consultant at Stavropol, explained the value of the fact-sheets provided by RosHydroMet: "*Based on fact sheets from RosHydroMet that identified a dangerous meteorological event – a soil drought in Kirovsky and Zelekumsky sub-regions of the Stavropol region in 2012 insurance companies had the capability to identify the insurance case of a dangerous meteorological event with the criteria specified in the contract within the duration of the insurance contract. Insurance was paid to two major agricultural producers: stud farm Druzhba and Kalinin communal farm in out-of-court procedure*".

Activities of RosHydroMet and its territorial nodes provide substantial support for agricultural producers and insurance companies in due exercise of insurance contracts, providing necessary aid in definite identification and parameters of insurance events.

3.5 Indonesia

By: Nelly Florida Riama

3.5.1 Introduction

Global warming and climate change have influenced to Indonesia's climate condition. Based on observation data of BMKG, it was found that the temperature in Indonesia had been increased about 0.75°C on the last one hundred years. In Jakarta for example, the temperature tends to experience an increase of 1.9°C over 28 years (period 1976 – 2003). Furthermore, climate change also has influenced the rainfall pattern in Indonesia. Based on BMKG's study in Kemayoran and Tanjung Priok (Jakarta Province), it shows that in Kemayoran, the number of rainy days tends to decreased every year. Otherwise, in Tanjung Priok, the number of rainy days tends to increase. The number of heavy rain days also tends to increase in both of Kemayoran and Tanjung Priok with different intensities every year. The climate change influence is not only felt in Jakarta province, but also in other areas in Indonesia. In some adjacent locations, the number of rainy days and rainfall intensities have increasingly become variable, and differences exists from one location to another (Sakya, 2016[31]; Sakya et al., 2016[32]).

Climate change may have a profound influence on the frequency of extreme climate conditions in Indonesia, and may become a trigger for hydro-meteorological disasters. From the National Board for Disaster Management (BNPB) data, 92% of disasters in the period of 2008 – 2016 were hydro-meteorological disasters, such as floods, landslides, drought and tornado's (*puting beliung*). In the last 10 years, approximately more than 1.4 million ha of land area was affected by flooding and more than 1.6 million ha was affected by drought (http://dibi.bnpb.go.id/data-bencana). Indonesia is one of the vulnerable countries to climate change, and Jakarta is the most vulnerable city in Southeast Asia (Yusuf and Fransisco, 2009)[33].

As a maritime country, Indonesia's climate is also influenced by El Niño Southern Oscillation (ENSO). ENSO causes changes in the length of the rainy season, and results in a higher rainfall variability. El Niño events are commonly associate with drought conditions. According to Sari (2017)[34], most of the extreme drought events in Java commonly occur during strong El Niño years. The La Niña events create the opposite conditions of El Niño, with generally an increase in rainfall amount. To support climate early warning, BMKG provides climate information including the days of onset of rainy seasons and dry seasons, rainfall analysis and forecast, monitoring of dry days, meteorological drought monitoring (SPI), monitoring of water availability, and flood potential maps (http://www.bmkg.go.id).

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[31] Sakya, A.E. 2016. Climate Change Projection and Its Impact on The Achievement of National Production Target in Paddy, Soybean and Corn (2016 - 2019). Presentation for National Paddy Seminar. 31 August 2016, Sukamandi, Indonesia.

[32] Sakya, A.E., Nurhayati, N. and Florida, N. 2016. Bringing Down Climate Knowledge to Enhance Farmers' Adaptation. p. 35-53 in: Case Stories of Climate Change Adaptation in Southeast Asia. SEARCA, Philippines.

[33] Yusuf, A.A. and Fransisco, H.A. 2009. Climate Change Vulnerability Mapping for Southeast Asia. https://www.idrc.ca/sites/default/files/sp/Documents%20EN/climate-change-vulnerability-mapping-sa.pdf

[34] Sari, N. 2017. Study of Drought Characteristics in Java Island. Buletin Informasi Iklim dan Lingkungan Vol. V-May 2017, 75-84.

Climate change will affect various sectors which are sensitive to climate conditions, such as the agricultural sector, fishery, health, transportation, tourism, and many others. Agriculture, as it was mentioned, is one of the highly sensitive sectors prone to climate variability and extreme climate events, such as droughts and floods. These extreme climate events can cause the largest natural disasters in Indonesia. Climate variability and change that occurs, when viewed from the side of the agricultural sector would be more complicated to effectively deal with. For example, small-scale farmers still more often rely on nature (nature-based), a traditional indigenous knowledge (local wisdom) and do not base farming management on agro-meteorological observations (observation based).

3.5.2 Climate Field Schools in Indonesia

Responding to these extreme climatic conditions, the Indonesian government has issued in 2011 the Presidential Instruction No. 11 on Securing Rice Production Under Extreme Climate Events (BAPPENAS, 2014)[35]. The programme aims to promote the importance of climate information in supporting the agricultural sector and to enhance the capability of farmers to make proper adjustments and adaptations to climate variability and climate change in Indonesia. Increasing climate literacy is one of adaptation step to strengthen local farming that shift traditional farming into observational (scientific) based farming. BMKG's adaptive effort to support agricultural decision-making in facing the threat of climate variability and change is by implementing Climate Field Schools (CFSs). A CFS aims to bridge the gap between farmer's knowledge and climate information, particularly on site, through a training process. Also, CFSs are expected to raise farmers' awareness on weather/climate information and its impact, in order to reduce crop loss.

BMKG runs the CFS program through a close collaboration with extension workers of the Ministry of Agriculture as well as with the farmers in the region. The extension workers serve as the intermediaries to facilitate farmers as the users in helping them to interpret and translate the climate information into an easy operational language used daily in the field. In CFSs, farmers learn how to observe climate parameters, access the climate information, and interpret and apply it to the field. For example farmers are trained to relate the expected amount of rain with the preferred type of crops to cope with climate variability and change.

3.5.3 Outcome of CFS

In general the CFS activities have been quite successful. Since 2010, the CFS programme has reached more than 3,600 extension workers in Indonesia and managed to improve the farmers' yields significantly. Not only men, but also more than 1000 women were trained in CFS's in order to support women empowerment. Post-test results indicated that understanding of climate information by CFS participants on average increased up to 70 – 75% which leads to the conclusion that the objective of the CFSs has been accomplished. The outcome of this process is indicated by the fact that the farmers confessed that their crop yield increased significantly (see Box 2). The learning-by-doing method serves as an effective process for transferring climate knowledge or climate information to farmers.

[35] BAPPENAS, 2014. National Action Plan for Climate Change Adaptation (RAN-API). National Development Planning Agency, Jakarta, Indonesia.

Box 2: Story Behind The Climate Field School

<u>The Story of Filmon Pello</u>

By: Dian Estey (2011)

The words La Niña and El Niño do not have any meaning for Filmon Pello, a farmer from Baubau regency, the province of East Nusa Tenggara. He felt that the last ten years of farming becomes harder than the previous years due to the extreme weather conditions. Drought has become a common condition. "*I have been a farmer for 20 years, and during this period I planted in the way I have taught by my great grandparents*," said Filmon. "*But the way I've done seems not to work anymore*," he added. Local beliefs have taught farmers, like Filmon to observe fireflies that indicate the coming of the rainy season or migratory birds that would indicate drought. But the signs are now no longer exists, forcing farmers to be more frequent in facing the crop failure. "*We think when it rains, it is the time to plant rice, but in fact the rain stopped until more than two weeks later*," said Filmon about the previous planting season last year. "*If I know farming becomes very difficult, maybe I'll stop farming for a long time,*" said Filmon again. Fortunately, there are friends who did not want him to change his profession and invited him to participate in a farmer group.

"*Finally, some staffs Meteorology, Climatology, and Geophysics Agency (BMKG) came to encourage us to study the relationship of weather and agriculture*," said Filmon. Together with 16 other farmers, Filmon began to learn about the patterns of La Niña and El Niño. The farmers were shown how to understand weather forecasts and information related to the agriculture. "*I believe that the rain and the drought is God's grace, but by knowing when it will rain and when it will dry is very helpful to determine the time of planting*," said Filmon still vigorously. Climate Field Schools (SLI) followed by Filmon was the result of cooperation between BMKG, Department of Agriculture and the Australian government (AusAID). "*Previously, I had not realized that what we have done will affect the weather, but now I understand what we're doing to the forests that provide many benefits during dry season*," said Filmon. "*Thanks to SLI now I understand they are strongly related*", still he said. Baubau regency, East Nusa Tenggara where Filmon lives is one of the regencies in the province that is highly vulnerable to drought events and the impact of heavy rains from El Niño and La Niña caused by geographical position.

"*The influence of La Niña and El Niño is no longer a strange word as often heard on television*" said Filmon with great pride. "*Now I understand that El Niño brings drought and La Niña brings the impact of heavy rain, it would determine the success of agriculture*," added Filmon. Currently, Filmon and fellow farmers prepare to harvest their first result this year. With muddy hands and the peanuts which had just pulled out from the land, Filmon and fellow farmers will no longer see the gloom. "*I am very pleased and I believe my life will be better now*," said Filmon with half a shout and confidence.

The Australian Government strongly supports BMKG in organizing activities in two places, namely Lombok, West Nusa Tenggara and East Nusa Tenggara Kupang. So far this activity has succeeded in increasing the understanding of 26 farmers about the effects of unpredicted climate conditions to their crop.

4. Recommendations

4.1 Quality of agro-meteorological information and predictions

There is a wealth of agro-meteorological information and predictions available from the National Meteorology and Hydrology Services in many countries, and many efforts are made to make this information available to potential users. There are a few good examples of how this type of information is used by farmers in different countries (e.g. China, Indonesia, Kenya, Russia, Senegal, USA, Australia). Examples range from insurance claims as a result of extreme weather conditions in Russia, spraying advice for strawberry growers in Florida, to crop management advices in China. However, only few examples exist where seasonal forecasts are used for agricultural decision making. These examples come from Australia (Box 1), Indonesia (Box 2), Kenya (Aura et al., 2015)[8] and Senegal (Roudier et al., 2014)[9].

There are two basic problems with the use of seasonal forecasts:

a) The reliability of the forecasts;

b) The probabilistic nature of the forecast information

If farmers are going to base an agricultural decision on a seasonal forecast, the forecast has to be clear and reliable. Taking a decision on a false forecast can mean a serious loss of investment if the season turns out to be different from what was predicted. It is therefore recommended to investigate the reliability of seasonal forecasts for a large number of locations, and determine the credibility of seasonal forecasts.

Providing seasonal forecasts in a probabilistic manner is a difficult concept for many of the potential users. Often seasonal forecasts are provided as 'above average rainfall', 'average rainfall', or 'below average rainfall'. In many cases farmers are more interested in the distribution of the expected rainfall, and whether they may expect dry spells or excessive rainfall events. Hence a recommendation is to improve the seasonal forecast information, and make it more meaningful than a simple probabilistic rainfall forecast.

4.2 Communication of agro-meteorological information to farmers

Communication agro-meteorological information to farmers and other potential users can be done in many different ways, but it depends on the level of technological advancement of a country what the best way is. Advanced countries like Australia and the USA use internet websites as well as mobile phone apps to communicate agro-meteorological information. In less advanced countries this type of communication sharing is less obvious, and the information provision relies more on traditional communication channels, such as radio broadcasts, newspapers, and bulletins. The fast spreading of mobile phones even in developing countries, including Africa, provides a huge opportunity to make use of SMS text messaging to spread agro-meteorological information. Many efforts are underway to make use of mobile devices to spread to information, and it is recommended to evaluate different communication strategies and determine how effective these strategies are in reaching the stakeholders.

Apart from reaching the users of the information, there are also issues of the type of information that is communicated. The agro-meteorological information should be site-specific, understandable and meaningful to its users. In other words, the user should be able to base farm decisions on the provided information, which may mean that the information is not just about current and expected weather conditions, but also includes targeted advices for crop choice, crop management, land management, and livestock keeping. It is recommended to evaluate examples of successful communication of agro-meteorologically based agricultural advice and derive a common strategy for development and communication of agricultural advices to the potential users.

4.3 Training of extension staff and farmers in the use of agro-meteorological information

Making use of agro-meteorological information for decision making can be a cumbersome process that may require assistance from extension staff. It is not only about the means of communication, but also about the interpretation of the information and how it can be used to improve agricultural production. The Climate Field School concept, as for instance used in Indonesia, is one of the most successful ways of training extension staff and farmers in the use of agro-meteorological information in less developed countries. It is recommended to learn lessons from past and current CFS's, and to stimulate CFS programmes in other countries where extension staff and farmers are not yet familiar with the potential applications of agro-meteorological information and forecasts.

4.4 Examples of successful applications of agro-meteorological information

The case studies presented in chapter 3 are only providing a limited overview of current agricultural decision support and extension services. There are probably many more examples of successes that have not been included yet. A more systematic search in the scientific literature, as well as on the internet could probably lead to a longer list of success stories that will help to improve climate services for agriculture. It is thus recommended to continue the activity on updating the list of successful case studies and deficiencies of agricultural decision support and extension services.