Practical Approaches to meet user requirements for climate forecasts and agrometeorological advisories for rangelands and wild fires

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Abstract

The delivery of regular agrometeorological advisory and weather forecasts for agriculture is meant to serve an important segment of the county's economy. The development of this service is necessary since modern day agricultural operations are becoming increasingly dependant upon detailed and accurate predictions of meteorological elements. Meteorological information is important for making many operational decisions and agriculturalists need weather information both for long range or strategic decisions and for short range or tactical decisions. In this paper an attempt is made to discuss the meteorological conditions that influence agriculture, rangelands and wild fire.

Introduction

A national meteorological or other agrometeorological service contributes to the national economy, and obtain best recognition and remuneration for the investments made in agricultural meteorology, throughout the effective use of information by the agricultural community in the widest sense. Improvements in agricultural production may well occur first where the inputs into agriculture are the highest. Such inputs are of a different nature: genetic material, energy, water, adapted use of the soil and of the landscape and plant nutrients, management and of course weather. Of those inputs only the weather is free of charge (Baradas, 1978), and its influence has been relatively little exploited (Rijks, 1991). User tailored weather information for planning, adaptation of the system and day to day operations involving the dosage and timing of application of inputs, is one of the major factors that can increase the efficiency of these measures and help to reduce the risks on the investments made.

This presentation has two parts. The first part deals with the weather forecast for agriculture and the second presents agrometeorological advisory for rangeland management and wild fire control. The major objectives of the paper are to summarize the available literature and recommend meteorologically based management practices in the aforementioned areas.

Weather Forecasts for Agriculture

The weather forecast for agriculture is a specialized forecast issued to serve an important segment of the county's economy. The development of this service is necessary since modern day agricultural operations are becoming increasingly dependant upon detailed and accurate predictions of meteorological elements. Meteorological information is important for making many operational decisions and agriculturalists need weather information both for long range or strategic decisions and for short range or tactical decisions.

The strategic decision input at the present state-of-the-art is limited to climatological information in the form of probability distributions. These allow the farmer to make such long range decisions as choosing the crop, its variety, selection of agricultural equipments, market etc. Once made, these decisions are irrevocable for the season.

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Tactical decisions may be divided into two types, the general routine decision, affecting cultural practices, and the high cost decision involving the operation of expensive crop protection systems. These decisions are revocable, although changing them may prove costly at times.

An agricultural weather forecast should refer to all weather elements, which immediately affect farm planning or operations. Though the elements vary from place to place and from time to time, it should include the following:

- Rainfall distribution and its probability
- Temperature
- Wind
- Humidity
- Dew
- Dry spells

Special weather forecast for agriculture

Special weather forecast for agriculture provides the necessary meteorological input to assist farmers in making decisions. The requirements for these special forecasts will vary during the season, from season to season and from crop to crop. These forecasts are normally issued for planting, applying agricultural chemical crop protection, forestry operations as well as for serving other weather related agricultural elements associated with the crop and its location.

Sowing

Seed germination is dependant upon proper soil temperature and moisture (Robertson, 1975). The farmer must know what the existing soil temperatures are and what the changes in the soil temperature and moisture can be. This will help him to avoid planting under soil conditions, which hinder proper seed germination and emergence and which consequently would require the replanting of expensive seed. Soil temperature forecasts are normally issued once daily prior to and during the normal planting season. They should give the present observed conditions throughout the area with a forecast of changes expected during the succeeding few days or more.

Application of Agricultural Chemicals

The critical factors in the proper application and use of the chemicals are temperature and rainfall during the succeeding 24 hours and the speed and direction of wind (Austine et al., 1960). Temperature at the time of application and immediately following are extremely important and can determine its effectiveness. Rainfall can dilute or wash off the chemicals.

Control of plant diseases

Most plant diseases develop and spread in conditions of wet vegetation with a rate of development depending on temperature. Therefore effective and economic control of most diseases requires a vegetative wetting forecast. This forecast will include the number of hours which vegetation was wet from rainfall, fog or dew during the preceding 24 hours, the temperature during this period and a prediction of the hours of wetting and of and the temperature during the succeeding 24 hours (Austin, 1955; Post et al., 1963; Hogg et al., 1969).

Transportation of agricultural products

Most agricultural products must be transported fairly long distances from the places of production to the market place. During transportation the temperature of many crops must be held within very narrow limits to prevent deterioration and spoilage, and therefore the heating and cooling of containers may be required. An accurate forecast of the maximum and minimum temperatures along the normal transport line is needed to plan the type of transport equipment and its utilization (McDonald, 1967).

Forestry Operations

Forestry is a specialized agricultural activity, which requires special forecast relating to those weather elements which affect forestry management and operation. Day to day weather information is important, for example, to assist in planning the establishment of seedlings in the forest stand, and in controlling disease and insects.

Fire is one of the greatest problems of forest management. The moisture content of forest fuels derived from measurements of physical atmospheric parameters is used to determine when fire danger alerts should be issued. Day to day reports and forecast of temperature, relative humidity, wind, rainfall, and thunderstorms are needed (Austin et al., 1960; Turner et al., 1961).

Agrometeorological Advisories

General agricultural weather forecasts provide information to the farmer so that he can make his own operational decisions. This special type of advice is given only in advisories issued by agrometeorologists in cooperation with agricultural extension workers. These advisories may recommend implementation of certain practices or the use of special materials to effectively help or minimize possible weather related crop damage or loss. In the following two sections meteorological conditions that assist in monitoring grasslands and wild fire are discussed briefly.

Rangelands

Rangelands are part of the total land system used by mankind. They are the areas of the world where wild and/or domestic animals graze or browse on natural vegetation. Rangeland vegetation includes grasslands, savannas or open scattered tree forests, shrublands and small grassy areas within forests. Range vegetation may never have been distributed, or it may follow changes in land use, such as brush clearance or timber harvesting. Cultivation eliminates rangeland vegetation but abandoned crop land returns to rangeland, especially in areas of shifting cultivation.

Rangeland covers nearly half the earth’s land surface (47%). Nearly half of this total area lies in the tropics and sub tropics. The world’s tropical rangelands support vast herds of domestic animals such as cattle, sheep, goats, water buffalo, camels, donkeys and horses. About one third of the world’s population live on these rangelands (Table 1). The tropical rangeland supports nearly a billion domestic animals and almost as many people. In some tropical lands most notably in Africa, great numbers of wild animals share the ranges with humans and their herds and flock (Heady and Heady, 1982).

The importance of rangelands/grasslands is at least threefold. They represent the habitat for many wildlife species, they protect the soil resource against both hydric and eolic erosion, increase soil’s organic matter content and facilitate water infiltration. Grasslands also provide food and water for grazing animals, which transform the dry matter into milk and meat.

Table 1. Human population and number (in thousands) of domestic livestock in tropical rangelands areas of the world (Heady and Heady, 1982).

Area	Human Population	Cattle	Sheep and goat	Horses and donkeys	Camels
Africa	206795	128 484	65 521	8 175	9 410
Australia	12 755	27 357	162 937	450	2
India	547 950	176 750	4 300	1 930	1 130
Mexico and Central America	86 280	41 648	6 579	12 842	0
South America	149 035	56 114	68 694	22 362	0
Southeast Asia and the Pacific	327 550	20 013	7 480	650	2 469
Total	1 330 365	450 366	315 513	46 429	13 0111

Operational Agrometeorological services for rangeland/pasture

The agrometeorological data essential for the management of rangeland/pasture consists of three sub systems. They are:

- An agrometeorological observation;
- A sub system for the collection, processing, transmission and storage of agrometeorological data;
- A sub system for the interpretation of agrometeorological data to the user (Danilov et al., 1996).

i. An agrometeorological observation sub system

The agrometeorological observation consists of land, arial and satellite observations. The conditions required for the organization of land observations of rangelands/pasture are a knowledge of observational requirements, regularity over the whole network of stations of these observations and accuracy of the observations and their presentation in suitable format. The observations should be recorded in accordance with specially prepared instructions, which should include their duration and the form in which their results are to be recorded. These instructions are needed to be reviewed every 10-12 years with a view to introducing new observation methods and adapting the scope of observations to the real time needs.

A special feature of the observation in hot, arid and cold regions is the vastness of their territories. Individual sample land observations in such territories cannot objectively reflect the variability of the agrometeorological conditions in space and time, the state and dynamics of the development, growth and productivity of the grasslands, the condition of grazing livestock or various stock breeding operations that are carried out.

ii. The sub system for the collection, processing, transmission and storage of agrometeorological data

The collection of primary data on the state of the environment and its individual components, their preliminary processing (coding, control and distribution) and transmission along communication channels is a huge task. The volume and duration of the transmission depends on its final use. The main function of the sub system is to ensure the processing of data at different levels and to disseminate information to a wide circle of users.

iii. The sub system for the interpretation of agrometeorological data to the user

The sub system is based on scientifically developed methods, tested in practice. The quantitative and qualitative evaluation and forecasting of the condition, growth, development and yield of pasture vegetation as well as provision of advisories on the state and productivity of stock breeding is all carried out by a group of experts. The efficiency of these methods depend largely on the sound theory on which the methodology is based on relating to the complex agrometeorological and ecological variables and the development, growth and productivity of pasture and grazing agricultural animals.

The functioning of the whole system for pasture stock-breeding obviously depends on the establishment of close interaction between all the three sub systems, with the cooperation from experienced agrometeorological observers, telecommunication experts, programmers, agrometeorologists and other experts.

The effects of meteorological factors on range vegetation

Meteorological factors have a direct relationship with the distribution of species, photosynthesis, growth and development, response to fertilization, insect pests, quality and animal performance. They are discussed briefly in the following paragraphs.

i. Distribution of species

Temperature is one of the most important factors that control species distribution. Data from Alaska, Guatemala, India, Japan, Kenya, Nepal, Northern Canada, Russian Federation, Tanzania indicate that tropical and warm season grasses of the *Eragrostoidea, Panicoidea* and certain species of the *Oryzoideae* and *Arundinoideae* are found at less than 2300 m elevation. At higher elevations, in tropical and subtropical regions, no warm season grasses are found (Kawanabe, 1981).

ii. Photosynthesis

Under non limiting conditions, the amount of photosynthetically active radiation intercepted by leaves is the main factor controlling the photosynthetic rate (PR) in C4 grasses (Cresswell et al., 1982). High temperature, however,affects PR especially in C3 legumes. Ludlow (1980) found that in two legumes (*Calopogonium mucunoides* and *Vigna luteola*) light use efficency declined linearly with temperature between 15 and 45°C, but in two C4 grasses (*Pennisetum purpureum* and *Melinis inutiflora*) light use efficency was independent of temperature between 15 to 40°C, declining rapidly between 40-50°C.

iii. Growth

Growth defined as irreversible dry matter accumulation and evaluated often by relative growth rate (RGR) is closely related to light intensity and temperature. In an evaluation of 8 tropical, 6 temperate grasses and one arctic grass, most temperate species had higher RGR than tropical species at low temperatures, but the opposite was true for high temperatures (Kawanabe and Neal-Smith,1980).

iv. Response to fertilization

Grass response to fertilization is rainfall dependant, specially N fertilization (Widenfeld, et al, 1984). Response to P fertilization is conditioned mostly by initial soil P levels. It is known that legumes, which often are found in grasslands, respond mostly to phosphorous, as they are able to fix nitrogen from the air. The response to phosphorous is also rainfall dependant. Guillard (1983) found that *Townsville stylo* increased dry matter production in response to phosphorous only in years with above average rainfall.

v. Insect Pests

Insect pests are important in tropical and subtropical areas because temperature is not a limiting factor as in temperate regions (CIAT, 1976). The conditioning factor is therefore moisture, which determines the amount of food available.

Wild fire

Weather factors favouring wild fire

Fires occurring under natural conditions are subject to the same natural laws of combustion as any other types of fire, even though the conditions under which they burn are seldom simple or uniform. Weather sets the stage for forest fires primarily through the control of the moisture content of the forest fuels. The control is exerted mainly by rainfall and dew, which increase the fuel moisture content, and by low atmospheric vapour pressure combined with wind, which reduce the moisture content of fuels. The effect of these meteorological elements is dependent on the amount, types, physical disposition and exposure of fuels in forests and bush country. Such fuels consist primarily of dead organic matter (chiefly cellulose and lignin) in associated sizes, arrangements and exposures.

i) Extended period influences

The fire season or fire danger period begins when the fuel moisture content decreases below the stage at which the fuel becomes potentially combustible. The onset of the danger season is the result of long-range pre-season influences, which may extend backwards for many months. For example, in the case of vegetation, which has an annual cycle of growth, the abundance of growth and rate of curing of such vegetation to the stage at which it becomes a significant fire hazard, is governed by rainfall, temperature and evaporation. The occurrence of killing frost is significant in deciduous forests for determining the onset of the autumn (fall) danger period.

In attempting to forecast both the onset and the potential severity of a fire danger period, the meteorologist should take account of the seasonal anomalies of the meteorological parameters of rainfall and temperature and, if correlations are available, of their effects on the rate of growth and curing of vegetation.

ii) Pre-ignition influences

Once vegetation and forest litter have reached the stage where they become potential fuels, the controlling factors in fire behaviour is the moisture content of the fuels as it is influenced by atmospheric moisture. The woody materials that make up the greater part of forest have the ability to take up and retain water in two ways:

(a) Such materials may contain an amount of moisture up to approximately one-third of the dry weight of the material as “bound water” which has been adsorbed on the interior surface of the material;

(b) Any moisture in excess of this amount, called the “fibre saturation point”, is held as free water. Free water is only acquired by woody materials in the presence of liquid moisture, usually in the form of rain or ground water, but occasionally as condensation from cloud or fog, or, under favourable exposures, as dew.

The loss of free water by forest fuels is closely related to evaporation, although capillary processes may limit the rate of loss where the moisture is deep-seated. Thus, in the initial stages of drying, the process is purely a surface effect and depends on the wind speed, fuel temperature and atmospheric vapour pressure. Once the fuels have dried to the " fibre saturation point" where no further free water is available, the process becomes a reversible one as absorption or desorption of bound water takes place in response to change in the relative humidity and temperature of the environment

Any attempts to relate change in moisture content of fully exposed fuels to values of ambient temperatures and relative humidity must take into account the effects of solar and terrestrial radiation. The meteorologist's interest in the distribution of moisture content of forest fuels is not primarily because of any utility as a forecasting tool but rather to assist him in interpreting past weather in terms of forest inflammability. Forest fire protection agencies however, regard this as a matter of prime importance, and have developed a number of methods for taking routine observations of the moisture content of significant fuels or for estimating the moisture content from meteorological parameters.

These methods, are in general of three kinds (Turner et al., 1961):

(1) The routine weighing standardized indicators in the form of rods or slats of a known dry weight immediately after exposure under natural conditions;
(2) The insertion of hygrometer, suitably calibrated in terms of moisture content, into accumulations of forest litter;
(3) The derivation of an index of moisture content of one or more significant fuel types from a combination of purely meteorological parameters, past and present. Such indices have been developed in a number of countries Turner et. Al. (1961).

Burning as a management practice

Large areas of rangelands are repeatedly burned every year either by design, mistake or natural causes. Because of its seeming omnipresence during the dry season, fire has greater and more direct influence on bush encroachment and herbage productivity of many grazing lands than any other methods used for bush control.

Many reasons are given for burning. Among these can be listed several which fall outside the range management practices (Crowder and Chheda, 1982).

- Carelessness of honey hunters who burn so as to see bee trees and hives hung in trees and who smoke the trees and hives before collecting honey;
- Land preparation under shifting agriculture when fire gets out of control;
- Control the encroachment of undesirable plants, mainly bush types and obtain more desirable species composition. This is the foremost reason put forth for burning, and experimental evidence shows that burning retards the establishment and growth of trees;
- Stimulate growth out of season and improve herbage quality;
- Constraint tsetse fly, other biting flies and ticks which transmit disease; and
- The assumption that the ash remaining after burning helps in fertilizing the soil.

Development of fire weather forecasting

Properly standardized weather observations taken daily and at locations where readings are not seriously affected by unrepresentative features such as rock out crops, small bodies of water and so on are affecting predictors of daily fire potential (Akim, 1982). According to Turner and Lawson (1978) the weather elements needed for fire weather index calculations are those that influence: (i) the ease with which fires can be started; (ii) the rate of spread and difficulty of control of fires which are burning; and (iii) the effects of fire on environment.

(i) Rainfall:

In the tropics, where there is a well-defined fire season that is a period of low or no rainfall, the date of the last rainfall would have a relationship on aspects of the moisture content of the available combustible fuel. The number of rainy days in the tropics is usually short, while the number of rainless days, especially in the dry season is considerably longer. It is therefore feasible to record the possibility of wild fire starting when caused by ignition source.

(ii) Temperature:

Although there may be little or no rain for a fairly long period, other climatic factors like high humidity and low temperatures may delay or prevent fine fuel ignition. The climates of the tropics however, indicates that during the dry or fire season, the highest temperatures and lowest relative humidity values are recorded. After the effects of rain have been overcome, temperature and relative humidity and wind speed have direct effects on the moisture content of the fine fuel plant materials (Van Wagner, 1974). The drying factor is required for the prediction of a fire index. Temperature affects the evapotranspiration process, it therefore speeds up the rate at which dry combustible plant matter is made available for ignition.

(iii) Relative Humidity:

Relative humidity has been used for long periods in temperate countries to give a quick assessment of the degree of fire danger. Air relative humidity calculated at noon has influence on the state of the dryness of available combustible plant matter. In addition to temperature and wind speed, relative humidity has influences on the fire weather.

(iv) Wind Speed:

Fire weather index is also influenced by wind speed by affecting the rate of drying of the combustible fuel and the rate of spread of the fire, which is also influenced by the moisture content of the fire susceptible fuels.

Fire Danger forecasts

If the weather forecast for tomorrow gives the actual values of the expected wind, temperature and relative humidity, these figures may be used to work out expected level of fire hazard.

Operational Agrometeorological services in Ethiopia

Data and information available in NMSA

The meteorological data collected and disseminated by NMSA could be divided into two. These are observational raw data and processed or analyzed data. These data are found either in numerical, text, table, graph, or maps forms.

- **Observational raw data** : these are data collected from the national conventional & upper-air stations and from the international network through satellite. The observational data set includes: wind speed & direction, visibility, dry & wet bulb temperatures, dew point temperature, maximum & minimum temperatures, atmospheric pressure, air humidity, evaporation, cloud type & amount, rainfall amount & intensity, significant weather such as gusty wind, radiation and soil temperature at different depths.

- **Processed or analyzed data**: These are prepared in the form of advisory bulletins and includes:

  - **Weather Outlook**:

    The weather outlook is given at different time scales based on the needs of different sectors. The outlook is given on 24, 48 & 72 hours, ten day, month and seasonal (four months) basis. For the monitoring of agriculture, rangeland and wild fire the forecast for three days and above are very important.

  - **Agrometeorological bulletins**:

    Agrometeorolgical bulletins are disseminated every ten days or month and season. The bulletins incorporate the rainfall assessment in terms of amount and anomaly, crop information (from NDVI and phenological report); Weather outlook and the impact of weather on agriculture.

Weather information are transmitted from meteorological stations by means of single side band (SSB) radio and telephone at least from 55 stations every ten days and crop phenological information from 30 stations. Besides, the NDVI picture and the map depicts rainfall estimations are collected from Satellite data reception and processing Unit in NMSA. Weather information contains maximum and minimum temperature, rainfall, relative humidity, wind speed(m/sec) and duration of sunshine hours while the crop information comprise three major food or cash crops of the area, including their phenological phases, occurrence of pests and diseases and their extent of damage, moisture condition of the field and general condition of the field. Moreover, weather outlook for the coming time interval is also received from the weather forecast team. Based on the above information the bulletin is prepared on a ten day, monthly and seasonal basis. The team is also issuing ten day flash reports during the Belg and Kiremt seasons. The agrometeorological bulletins includes the following:

Summary: gives the highlight on the rainfall condition of the preceding time. Moreover, it highlights the current rainfall situation and its impact on agriculture.

Weather assessment

- **Rainfall**: The rainfall assessment is done in to two parts. The first part deals with the rainfall amount discussion. Here, the amount of rainfall received during the specified time interval is presented. Moreover, the highest rainfall amounts received during a day or the specified time interval is discussed. Secondly, the rainfall anomalies are presented. In this case the rainfall distribution in relation with the long-term average value is discussed. These are accompanied by maps.

- **Temperature:** the extreme temperatures that are hazardous to plant growth or agricultural activities are presented.

- **Weather outlook:** The expected weather condition during the coming time interval is presented.

- **Agrometeorological conditions and impacts on agriculture:** In this section the impact is given into parts the first one deals with the impact assessment of the previous weather on crops. Here crop phenological data and satellite derived pictures along with the weather data are used. The second part deals with the impact of the coming weather on crops. The input data used here are the weather outlook for the coming period, the crop growth stage and the future water requirement of the crops.

The bulletins are produced on time and distributed to all agricultural and other related organizations in the country with minimum delay.

The flash report is a very short summary of the rainfall condition and highlight the impact. It also includes the weather outlook for the coming dekad. It is produced with the available meteorological data. It is disseminated during the first two days of the next dekad to the decision makers and other higher officials in the capital and sent by fax to regional authorities. This bulletin is circulated only during the Belg and Kiremt rainy seasons.

Rainfall and Vegetation assessment_ -

The bulletin includes rainfall assessment purely based on the satellite data - rainfall distribution, comparison with the previous dekad (ten day) period and comparison with the 1991-95 satellite average. The vegetation monitoring parts assess the density of vegetation using NDVI. The bulletin is produced every ten days.

Conclusions

In the data collection scheme the use of remotely sensed data is very essential. Therefore ground observations should be supplemented by remote sensing.

The weather has a direct impact on the lives and livelihoods of the people throughout the world. Improving the flow of weather information to the public and the policy makers can improve day-to-day decision-making and influence critical decisions in many sectors of the national economies. This is particularly true in Africa, where many societies live with the ever-present risk of drought and famine and where weather forecasts can impact on the decision-making process of farmers and in every part of the society. In view of the influence of weather and climate in every facets of economic activity, timely dissemination of weather and climate forecasts are important to reduce national vulnerability to weather- and climate-related natural disasters.

The agrometeorological advisories produced should be regular (weekly, ten day or monthly) and should reach the end user on time so as to help him take appropriate management action. The advisories could be in the form of newsletters or bulletins. Thus information dissemination and interaction among the farmers, extension workers and other users is of great importance. Figure 1 indicates the schematic representation of the ways of data collection, analysis and interpretation and dissemination of the final results.

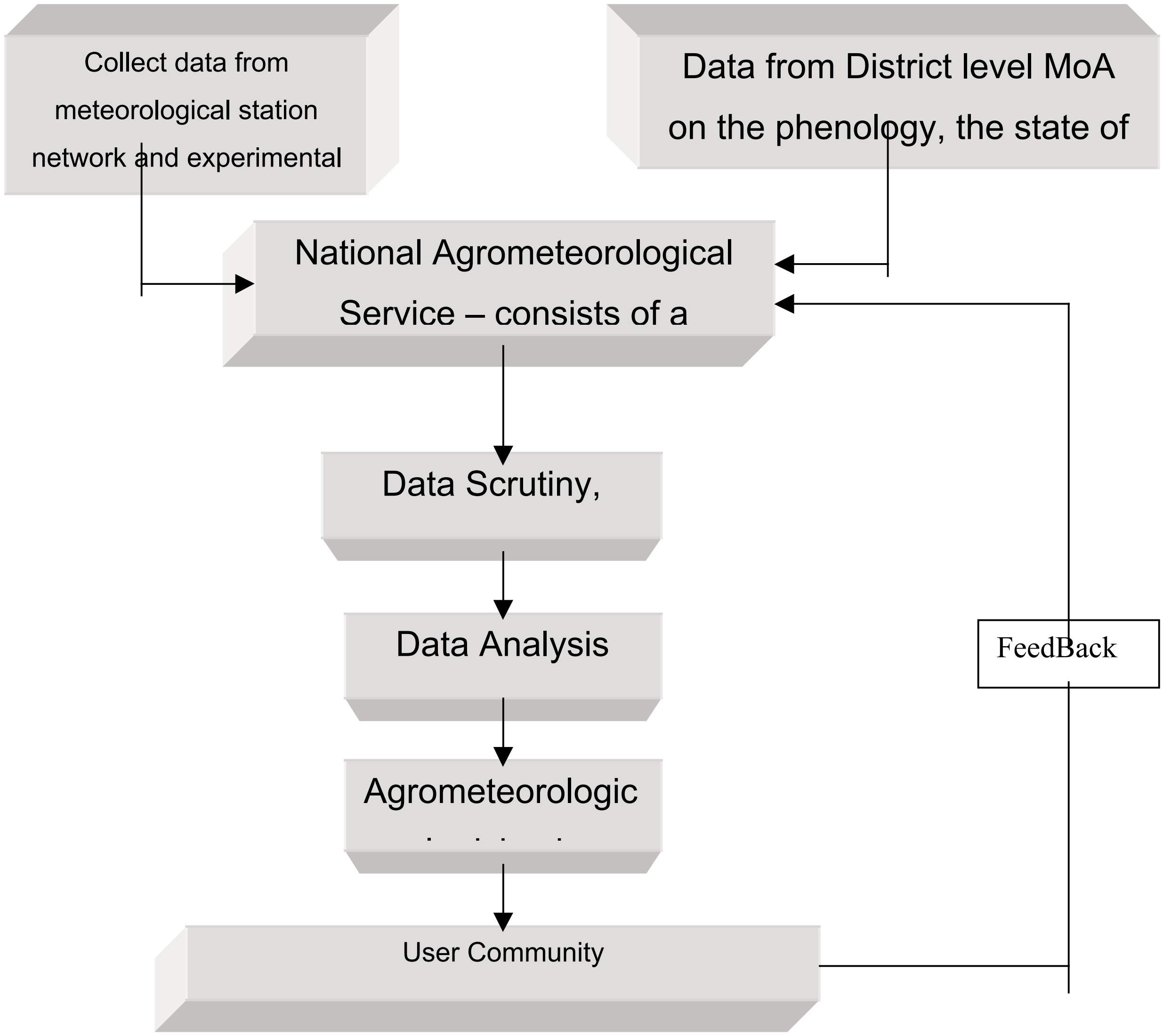

Figure 1. Schematic representation of practical approaches to meet user requirements for climatic forecast and agrometeorological advisories

Wildland fires are experienced in most tropical countries, which enjoy clearly marked wet and dry seasons during the year. Although wildland fires are very extensive in these areas covering about 50% of the tropical land, the huge economic losses due to the problem have not been fully assessed in most countries. Thus the significance of the problem has not been properly brought up for adequate government action in these countries. Wildland fires initiated mainly by man in the tropics are largely uncontrolled, due to lack of adequate fire fighting equipment and in many cases there is no real desire to control the fire. The damage from such fires to forest plantations, farmlands and houses is extremely high.

Prediction of wild fires is almost non-existent; while synoptic meteorological stations are inadequate, the data collected are not processed and utilized for making fire danger forecasts even where this is feasible. This is due mainly to the lack of knowledge of the application of meteorology to solving the problem.

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