Drought Early Warning Systems in West Asia and North Africa

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Abstract

The North Africa/West Asia region is characterized by considerable diversity in climatic conditions. Most countries of the region have a high degree of aridity and pronounced rainfall variability in large parts of their territories and are therefore highly vulnerable to drought. Drought is an inherent characteristic of climates with pronounced rainfall variability. In the last few decennia, there has been a marked increase, or at least a perception of increase, in the number of droughts in the region, particularly in North Africa.

Drought early warning systems, as they have been set up in many other countries of the world, are virtually nonexistent in the North Africa/West Asia region. Drought early warning systems of the region function at two levels, international and national.

The international level is the FAO-coordinated GIEWS, which is, strictly speaking, an information network for early warning of food shortages. One of the key characteristics of the international food security monitoring system is that it is integrated, draws on all possible alert indicators (economic, meteorological, agronomic, social, nutritional) and uses extrapolation tools (GIS and remote sensing) to assess the food security outlook.

National-level integrated drought monitoring systems are not operational in the region. In general, there has been limited coordination of information from sources, such as water supply or irrigation authorities, agricultural extension services, meteorological departments, and NGOs, about the extent and impact of drought.

In most countries of the region, meteorological networks are adequate, being well equipped and well sited, representative for major agroecologies and agricultural production areas. Notwithstanding these advantages, the meteorological departments of the region are at the moment poorly prepared to function effectively in drought early warning systems because of inadequate analytical tools for drought monitoring, unsuitable information products, and insufficient data sharing.

The region has an overwhelming need for modern and effective drought early warning systems. To develop such systems, challenges have to be met, as related to the reliability of long-range forecasts, selection of appropriate drought indicators, spatialization tools, agroecological characterization, and institutional arrangements.

In the North Africa/West Asia region, no significant relationships have been confirmed between droughts and ENSO events. For this reason, long-term forecasts for a whole season or longer are not considered reliable.

Different types of drought require different drought indicators. Some indicators are more suited to monitor agricultural drought, others to assess hydrological or meteorological drought. The assessment of socioeconomic drought requires socioeconomic and nutrition-based indicators.

The choice of drought indicators should also be guided by the goal of the drought assessment, which can be to assess intensity, exceptionality, or impact of drought. To assess agricultural drought, indicators based on the water balance are preferred.

Institutional arrangements may determine success or failure of drought early warning systems. The key characteristic of well-functioning early warning systems, whether for drought or food security, is that they are small but multidisciplinary and tightly integrated units. Of critical importance for the success of all early warning units is the free flow of information.

Importance of Drought in the North Africa/West Asia Region

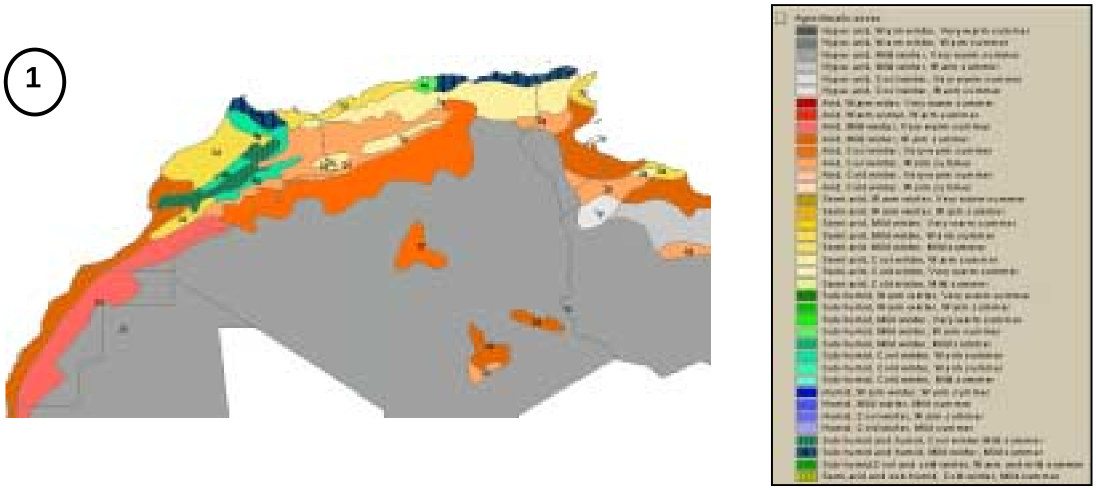
The regions of West Asia and North Africa are characterized by considerable diversity in climatic conditions. This is evidenced by the map in Figure 1, which shows the agroclimatic zones according to the UNESCO classification for the arid zones (UNESCO 1979). As the map indicates, the region contains widely different moisture regimes ranging from humid to subhumid, semiarid, arid, and hyperarid. In addition, temperature regimes vary considerably, particularly as a result of differences in altitude and, to a lesser extent, oceanic/continental influences. With the exception of Turkey, the countries of the region have a high degree of aridity in large parts of their territories (Table 1) and are therefore highly vulnerable to drought.

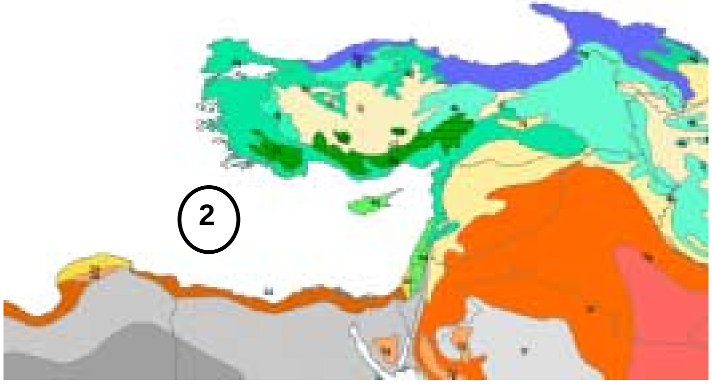
Drought is mainly the result of deficient rainfall. One of the many definitions of drought is “a deficiency of precipitation from expected or ‘normal’ that, when extended over a season or longer period of time, is insufficient to meet demands” (Knutson et al. 1998). From this definition it is clear that drought is an inherent characteristic of climates with pronounced rainfall variability.

Rainfall variability is considerable in the North Africa/West Asia region, irrespective of the moisture regime (Figure 2). Figure 2 shows the annual rainfall variations for 4 stations in different agroclimatic zones. It is evident that rainfall variability is not confined to the low rainfall areas of the region. The large amplitude of the variations is typical for the region as a whole.

One of the major characteristics of drought in the region is that it is essentially not predictable. As will be discussed later in this chapter, no significant correlations with any particular weather anomalies have been confirmed.

Another feature of drought in the region is that it can strike any time of the season and varies with location. Early-season, mid-season, and late-season droughts are all possible. In addition,





EXPLANATORY	
Moisture	**Annual**
Hyperarid	< 0.03
Arid	< 0.2
Semiarid	< 0.5
Subhumid	< 0.75
Humid	>=
Winter	**Average temp. winter**
Warm	> 20
Mild	> 10
Cool	> 0 °C
Cold	<= 0
Summer	**Average temp. summer**
Very	> 30
Warm	> 20
Mild	> 10
Cool	<= 0

Figure 1. Agroclimatic zones of North Africa (1) and West Asia (2) (after UNESCO 1979, with modifications).

Table 1. Countries of the region with arid zones.

Country	Degree of Aridity					Very Dry Areas	
	HA	A	SA	SH	H	Sq. km	%
Algeria	do	as	As		In	1,245,000	53.8
Egypt	do	in				508,000	50.9
Libya	do	as	in		In	1,162,000	71.9
Mauritania	as	as	in			733,000	69.8
Morocco		as	as	in	In	110,000	26.9
Tunisia		do	as		In	72,000	46.9
Israel	as	as	as			6,000	29.9
Jordan	in	do	in			50,000	55.6
Lebanon			do			1,000	11.4
Syria		as	as	in		115,000	61.4

<u>Explanatory notes</u>:

(a) degree of aridity:
HA: hyper-arid; A: arid; SA: semiarid; SH: semihumid; H: humid

(b) The symbols used refer to relative importance within the country:
in: inclusion (< 5% of country)
as: associated (at least 5-10% of country)
do: dominant (> 50% of country)

(b) The category 'very dry areas' is derived from the FAO Soil Map of the World as areas where Xerosols and Yermosols occur. This is a valid approach since the latter soils are defined in terms of their soil moisture regime, which is arid (Xerosols) or very arid (Yermosols).

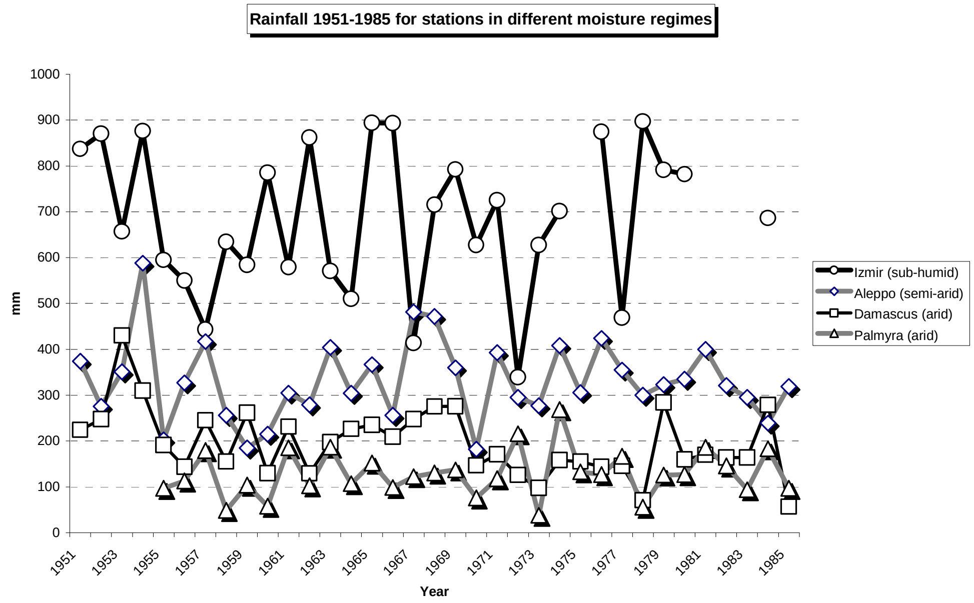


Figure 2. Rainfall variability in different agroclimatic zones.

they can be very localized. This local confinement of drought is illustrated in Figure 3, which shows the cumulative rainfall deviations for Aleppo, Damascus, and Palmyra in Syria, three locations a few hundred kilometers apart, but with different patterns of longer-term positive or negative anomalies.

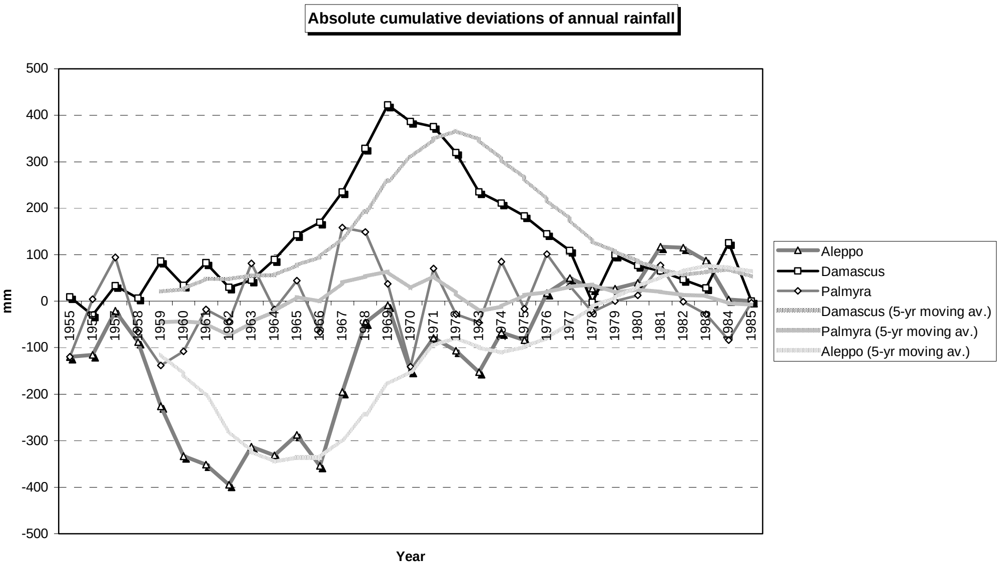


Figure 3. Patterns of positive and negative precipitation anomalies for 3 locations in Syria.

Droughts in the region are complex in pattern, effects, and impact. Droughts express themselves by reduced rainfall, which is directly used by rainfed crops and rangelands; reduced runoff, which fills small dams or recharges ground water tables; reduced streamflow; and lowered water reservoir levels. Assessing the impact on these various natural resources therefore requires different indicators.

The main effect of drought is a reduction in agricultural productivity, which ripples through society via the linkages of agriculture with other economic sectors. If severe or persistent enough, droughts put added pressure on urban resources through increased migration of vulnerable rural people from drought-stricken areas. In marginal areas where opportunistic cropping has occurred in years of above-normal rainfall, a subsequent return to normal or below-normal conditions can initiate wind erosion and accelerate existing processes of desertification. This has been the case, among others, in the Syrian steppe (Debaine and Jaubert 1998).

The impact of drought depends on its timing and duration, particularly in relation to growth stages of particular crops and the tolerance of individual crops or cultivars to drought. Land use change may also affect the impact of drought. Vulnerability to drought may increase, as the above example of expansion of rainfed cropping into marginal areas demonstrates. However, land use intensification may also decrease vulnerability to drought, through the transition from rainfed to either partially or fully irrigated cropping systems.

In the last few decennia, there has been a marked increase, or at least a perception of increase, in the number of droughts in the region, particularly in North Africa. Although no clear trends of declining rainfall have been identified (Yacoubi et al. 1998), the apparent increase in drought events raises the possibility of increasing rainfall deficits in the region as a result of climate change.

As a matter of fact, the Intergovernmental Panel on Climate Change projects small increases in precipitation for the region, but these increases are likely to be countered by increased temperature and evaporation (Watson et al. 1997). According to the Panel, drought is therefore likely to increase and will have the greatest impact on the grasslands, livestock, and water resources of the marginal areas. Water shortage, already a problem in many countries of this arid region, is unlikely to be reduced, and may be amplified by climate change. In addition, drought may exacerbate existing land degradation problems and, through the added stress on limited water supplies, threaten the food security of some countries.

It is particularly in this context of climate change that drought issues are gaining interest in the region. Planning for drought becomes an unavoidable policy issue for governments of the region. Drought planning implies effective early warning systems, tactical planning for mitigation of drought impact, and long-term strategies for drought adaptation, particularly land use policies and technologies for drought-prone areas. The importance of drought planning is well recognized and governments of the region are fully cooperating with international organizations, such as FAO,[1] in the mitigation of food shortages, which are often related to drought. Nevertheless there are no integrated government structures that can deal with all aspects of drought planning. As a result, drought early warning systems, as they have been set up in many other countries of the world, are virtually nonexistent in the North Africa/West Asia region.

In the next sections, the situation will be described in more detail and suggestions for improvement will be made.

Status of Drought Early Warning Systems in the Region

Drought early warning systems of the region function at two levels, international and national. The international level is the FAO-coordinated GIEWS,[2] which is, strictly speaking, an information network for early warning of food shortages.

International Level

In many countries, particularly in Africa, FAO has helped governments establish specialized units, “Early Warning and Food Information Systems” (EWFIS), for food security monitoring. These units act as focal points within governments for collecting, processing, and communicating information on all the key variables that influence food security. The EWFIS use a well-established methodology of food security assessment, which is based on crop condition monitoring at regional and national levels and monitoring of food security at global, national, and subnational levels.

The crop condition monitoring relies on agrometeorological models, fed by data from meteorological networks, and supplemented, in data-sparse areas by low-resolution satellite imagery products, particularly cold cloud duration (CCD), as a proxy for rainfall, obtained from

Meteosat, and the Normalized Difference Vegetation Index (NDVI), as an indicator of crop stage and condition, obtained from NOAA.

At the global level, GIEWS monitors world food prices and estimates global food supply and demand.

At the national level, GIEWS monitors in particular a group of some 80 “Low-Income Food-Deficit Countries” (LIFDCs), in which food security is particularly vulnerable to crop failure or high international cereal prices. The standard instrument is the National Food Balance sheet, a regularly updated accounting system that monitors commercial imports and food aid deliveries and estimates the quantities of imports, including food assistance, which will be required to maintain consumption at normal levels. The main focus of this analysis is on cereals because up-to-date information on other types of food is often weak in many countries.

At the subnational level, the system focuses on vulnerable population segments and monitors indicators of food crisis such as local market food supplies, retail price rises, and evidence of individual and community responses to food insecurity. Such responses are sometimes referred to as “coping strategies” and include unusual sales of livestock or other assets, migration in search of food, consumption of wild foods that are not part of the normal diet, and a reduction in the number and size of meals. When they are available, data on malnutrition indicators are also monitored.

The GIEWS produces a wide range of regular reports, which cover global and national food security outlooks and are frequently updated. Some of these reports focus on particular regions, such as sub-Saharan Africa and the Sahel. Special reports and alerts are issued when food security emergencies arise in particular countries. More information about GIEWS, including reports, can be found on the relevant web page.[3]

The EWFIS are basically an international mechanism to avoid famine situations, and are therefore mainly situated in sub-Saharan Africa, where food insecurity is endemic. Within the North Africa/West Asia region, where drought but not food security has been a major problem, EWFIS have not been established. However, through FAO’s regional and national offices, information is compiled, from governments and intergovernmental authorities, that allows the GIEWS to assess the food security situation in individual countries that do not have EWFIS.

In cases of abnormal drought that may cause major production shortfalls and create exceptional food emergencies, GIEWS mounts rapid assessment missions, usually jointly with the World Food Programme, to the affected countries. On the basis of these visits, and with the inputs of government experts, ad hoc situation assessment reports to governments and the international community are prepared with suggestions on how to deal with the food emergency caused by drought. In the last few years, such assessment missions and reports, prompted by drought-induced food insecurity, have been prepared for most governments in the region.

National Level

One of the key characteristics of the international food security monitoring system is that it is an integrated one. It draws on all possible indicators (economic, meteorological, agronomic, social, nutritional) as well as extrapolation tools (GIS and remote sensing) to assess the food security outlook.

The main goal of the international monitoring system in the North Africa/West Asia region, as in other parts of the world, is to assess food security, not drought. Since the countries of the region have the financial means to import food in case of a production shortfall, drought has rarely been a threat to national food security, and has therefore not been the subject of a monitoring system in its own right.

National-level integrated drought monitoring systems are not operational in the region. Although drought affects major segments of society in the region, in general there has been limited coordination of information from sources, such as water supply or irrigation authorities, agricultural extension services, meteorological departments, and NGOs, about the extent and impact of drought.

In any drought monitoring system, meteorological services of the region have a critical role. Without meteorological data, and analytical tools that transform meteorological data into relevant drought indicators, droughts cannot be adequately monitored. In most countries of the region, meteorological networks are adequate, being well equipped and well sited, representative for major agroecologies and agricultural production areas. Obviously improvements are always possible, especially in servicing the more arid zones.

Nevertheless, at the moment, meteorological departments of the region are poorly prepared to function effectively in drought early warning systems. Major shortcomings are related to:

- inadequate analytical tools for drought monitoring;
- unsuitable information products;
- insufficient data sharing.

Most services still define drought as a negative anomaly from normal precipitation, in terms of absolute or percentile deviations. An example of an output of this type of analysis is provided in Figure 4, which has been obtained from the Turkish State Organization for Meteorology.[4]

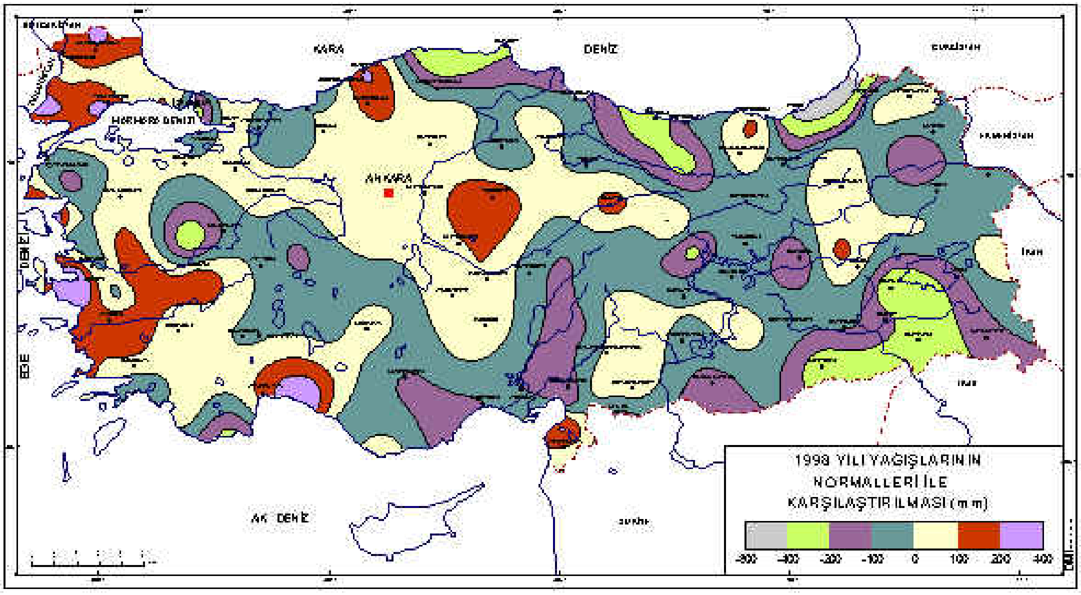


Figure 4. Deviations of 1998 annual rainfall from normal.

Well-established drought indicators such as the Palmer Drought Severity Index (PDSI), the Standardized Precipitation Index (SPI), or deciles are not used. Work on developing suitable drought indicators has started only recently in Morocco (e.g., Yacoubi et al. 1998) and Syria, and is not yet incorporated in operational drought monitoring.

In addition, the information is not used to monitor drought, but rather to characterize the climate during the ongoing year, month, part of the year, or agricultural year. There are no regular bulletins that target the agricultural user community or other stakeholders in drought mitigation, through interpretation of the available raw data and communication in terms of impact and seasonal outlook.

It can be argued with some justification that the production of such derived products exceeds the in-house expertise of most meteorological services, and should therefore not be their sole responsibility. However, the inter-institutional partnerships that are required to produce specialized drought information bulletins are much hampered by the common practice of meteorological services of the region to charge for meteorological data, even to other government departments. With exceptions (e.g., Turkey), the charges are often prohibitive and make no economic sense. As a result, the meteorological data bases, which are indispensable for basic analyses, such as drought risk assessment, cannot be accessed by the agricultural user and research community, which has the highest data requirements but the lowest financial resources of all potential users of meteorological data. In return, agricultural research institutes are not sharing their growing in-house expertise in agricultural applications with meteorological services. The exorbitant charging by meteorological services for data is one of the major handicaps to be overcome in order to set up effective early warning systems.

Conspicuously missing in this region are integrated spatial frameworks, such as agroecological zones, for relating anomalous weather conditions to static physical regions that are more or less homogeneous in land and water resources and land use, and for which drought conditions need to be assessed separately. Such spatial frameworks are highly relevant to the region given its great agroecological diversity.

Future Needs

The region has an overwhelming need for modern and effective drought early warning systems. All countries of the region have experienced, and continue to experience, very high population increases and increasing pressure on land and water resources, which threatens the sustainability of current land uses and exacerbates the impact of drought on rural populations.

Increasing awareness that droughts have mounting economic, social, and environmental costs, and may particularly hit vulnerable population segments is changing government's perception about the need for drought early warning systems. As a matter of fact, some countries have opted for a *comprehensive* approach, working toward integrated systems for drought management, rather than drought monitoring.

The key principles of drought management are:

- the approach is multidisciplinary and integrated;
- drought planning must cover different time scales and include, apart from short-term solutions to mitigate drought impact, long-term land use strategies ;
- consideration is given to both the biophysical and socioeconomic dimensions of drought;
- drought management is a key component of sustainable land use in drought-prone areas.

The main strategies for effective short-term and long-term drought mitigation are (ICARDA 1998):

- seasonal climate forecasts and early warning systems;
- better targeting of crops and cultivars to specific agroecological environments;
- natural resource management adapted to the limitations of drought-prone areas, in particular, crop breeding and crop management to increase water use efficiency; soil and water conservation, including water harvesting; and sustainable use of irrigation water;
- policy and institutional measures to facilitate implementation of drought mitigation practices, in particular, the conservation and harvesting of water, shifts to more adapted crops, etc.

The major challenges facing integrated drought management systems are:

- *Drought monitoring*: developing reliable indicators and forecasts and accurate spatialization of drought extent and intensity;
- *Drought impact assessment*: assessing sensitivity to drought of different agroecological land use systems and identification of vulnerable population groups;
- *Institutional arrangements*: creating effective multidisciplinary, multi-institutional focal points to coordinate national drought management plans.

In the following paragraphs, some of these issues will be discussed in more detail.

Feasibility of Seasonal Forecasts

Weather patterns in many parts of the world appear to be related to different phases of the El Niño-Southern Oscillation (ENSO) cycle. The existence of such linkages is now being used in operational early warning systems, such as FEWS, [5] to forecast rainfall patterns for the coming crop growing season. The basis for forecasting is that a particularly strong linkage exists between the warm-ocean phase of the ENSO and drought in southern Africa. Such correlations have proved to be useful in tropical areas and there is confidence it may soon be possible to predict, for southern and eastern Africa, certain climatic conditions associated with ENSO events more than a year in advance.[6]

In the North Africa/West Asia region, no significant relationships have been confirmed between droughts and ENSO events. This is probably because the effects of this global ocean-weather linkage, and therefore the weather, are substantially modified by more localized weather phenomena (e.g., the North Atlantic Oscillation), but also by very site-specific factors, such as topography, antecedent soil moisture and vegetation condition, and the nearness of large desert land masses. As a result, the countries of the region, or even parts of countries, have highly contrasting rainfall-generating mechanisms. For this reason, long-term forecasts for a whole season or longer are not considered reliable.

The current practice is to forecast the remainder of an ongoing season on the basis of statistical or empirical relationships between meteorological events, such as precipitation, in the beginning and at the end of the season. This practice is adopted, among others, by the Office National de la Météorologie of Algeria, which uses for the purpose the numerical climate model ARPEGE[7] of the Centre National de Recherches Météorologiques. The value of this approach for drought planning is doubtful. Some authors (e.g., El Mourid and Watts 1989) found no correlation in Morocco between autumn and spring rainfall, which is a critical period for crops, given the common occurrence of end-season drought.

Even where the correlations are highly significant, as is the case in the linkage between ENSO and East African rainfall, the forecasts usually retain a few highly likely rainfall patterns, each one with significant probabilities but different effects on crop condition. Because the probabilities for occurrence of each rainfall pattern are usually not negligible, they all need to be considered, which diminishes considerably the value of the forecasts for very early planning purposes.

This problem is illustrated in Figure 5, which provides for southern Africa the outlook for rainfall during the period January-March 2000, the most important months of the growing season. The forecast made in September 1999 (SADCC 1999) is expressed in terms of probabilities of different rainfall patterns according to climatic regions. The top figure for each climatic region represents the probability of above-normal rainfall, the middle figure the probability of normal rainfall, and the bottom figure the probability of below-normal rainfall. It is clear that only in a few cases can a scenario be dismissed as highly unlikely.

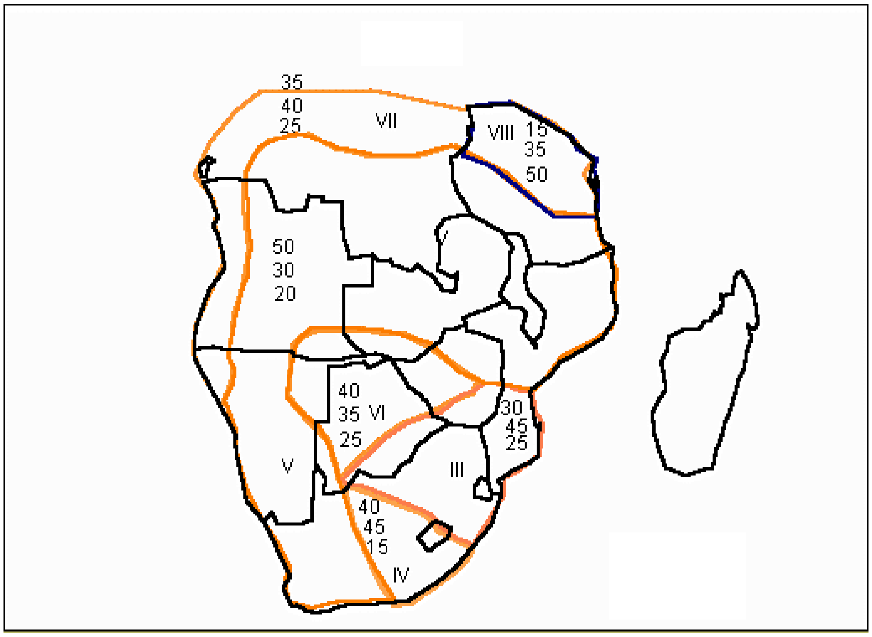


Figure 5. Probabilities of seasonal rainfall patterns for southern Africa (SADCC 1999).

Drought Indicators

The main criteria for early warning indicators of drought is that they are accurate, are responsive to changes in the moisture supply situation, are comparable across space and time, and aid decision making for drought mitigation at a sufficiently early stage and in individual regions.

Different types of drought require different drought indicators. Some indicators are more suited to monitor agricultural drought, others to assess hydrological or meteorological drought. The assessment of socioeconomic drought requires socioeconomic and nutrition-based indicators.

An exhaustive comparison of relative merits and disadvantages of different drought indicators is beyond the scope of this chapter. A review of commonly used drought indices, to assess agricultural, meteorological, or hydrological drought, has been prepared by Dr. M. Hayes of the National Drought Mitigation Center.[8] The best-known indices internationally are the Palmer Drought Severity Index (PDSI), Standardized Precipitation Index (SPI) and decile method. Some of these methods have been tested, with varying results, in the region.

The choice of drought indicators should also be guided by the goal of the drought assessment, which can be to assess intensity, exceptionality, or impact of drought. Indicators showing absolute deviations are better suited to assess drought intensity and are comparable across space, which may allow the production of drought intensity maps. An example of an intensity indicator is given in Figure 6, which shows within a growing season the cumulative deviations from normal of the actual evapotranspiration, a water balance-based indicator, for 3 years with different rainfall patterns.

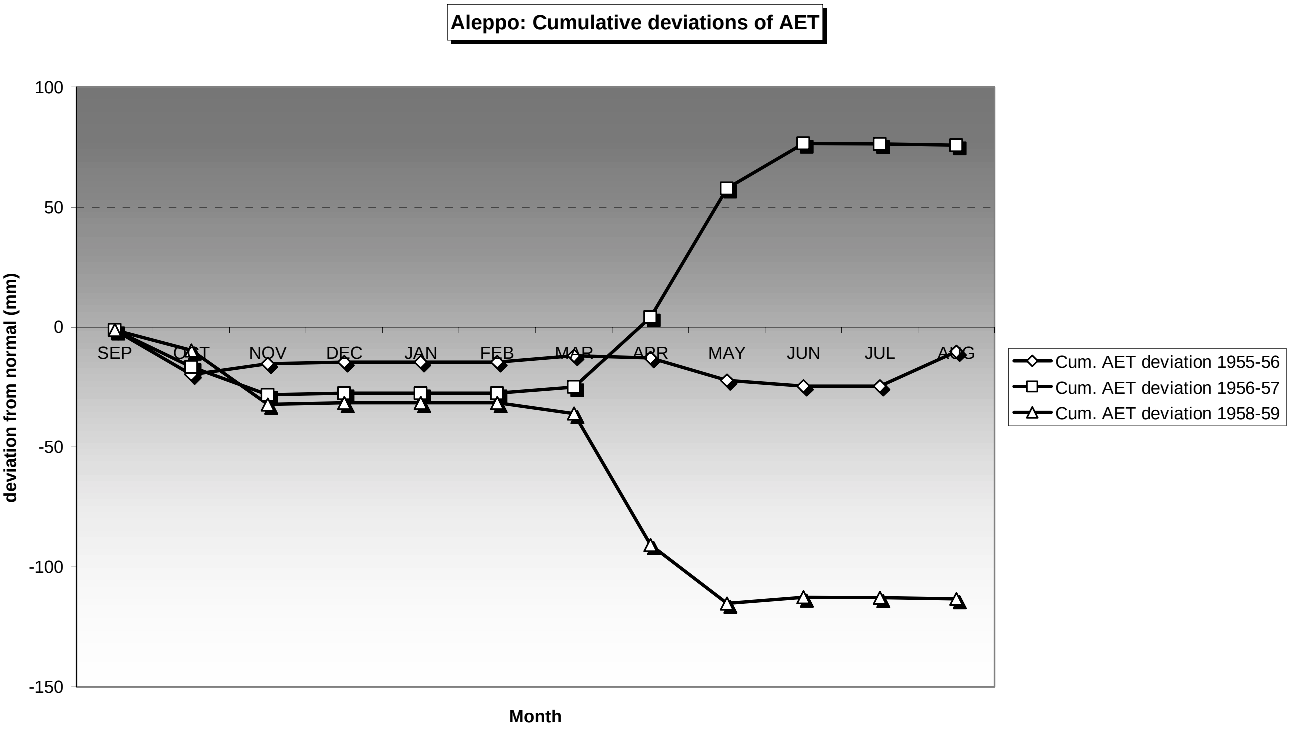


Figure 6. Example of the cumulative deviation of AET, an indicator of drought intensity, for Aleppo, Syria.

Indicators such as the SPI or deciles, which are based on fitting meteorological parameters to probability distributions, are more suitable for deciding on the exceptionality of drought events and may be a basis for providing aid such as emergency assistance and crop insurance.

Indicators to assess drought impact are much more complex and diverse, and need to be used with great caution, especially for forecasting purposes. Early warning systems for crop yield and production forecasting, such as those of FAO or the European Commission, use sophisticated crop yield models, based on a combination of crop growth simulation and production trend functions with remote sensing and GIS for spatialization. The information requirements of these systems, especially the European one, are very high, making them very expensive to operate and maintain.

It must also be noted that drought indicators have a useful “lifetime.” A typical example is the SPI, which needs to be calculated for different periods (e.g., 1 month, 3 months, 6 months, etc.). For each period, the interpretation associated with the index is different; for example, the 3-month SPI has a different meaning from the 1-month SPI.[9]

Agricultural Drought Indicators

To monitor agricultural drought, the most suitable indicators are those that are responsive to soil moisture status and are therefore based on the soil water balance. The reason is that the timing of soil moisture deficits in relation to crop water requirements and sensitivity to moisture stress is of major importance to assess the impact of drought on crops. At the same time, the indicators should be simple enough to allow straightforward interpretation.

In the course of a collaboration between the Syrian Meteorological Department and ICARDA, the feasibility of using a soil water balance-based indicator, the PDSI, as a drought index for Syria was evaluated. The main conclusion was that, although the PDSI is sufficiently responsive to assess agricultural drought, it is unsuitable for Syrian conditions because of the difficulty in obtaining the empirical weighting factors for each month and area. The index scale of the PDSI has apparently been calibrated on the basis of data available from the U.S. state of Kansas and has little meaning in terms of assessing the rarity of drought events under Syrian conditions. One reason for this is that potential evapotranspiration, an input to the water balance, is calculated by the Thornthwaite method (Thornthwaite 1948), which significantly underestimates potential evapotranspiration under arid conditions (Smith 1990; Choisnel et al. 1992). In addition, the calculation procedure appears unnecessarily complex, and the output is difficult to interpret in terms of drought impact or to assess the exceptionality of drought events, one of the key criteria for deciding emergency aid or compensation to farmers.

A simple but effective agricultural drought indicator, which can be derived from a generic water balance approach (Thornthwaite and Mather 1955), is the deviation of actual evapotranspiration (ETa) from expected under average climatic conditions. Because the ceiling for actual evapotranspiration is the potential evapotranspiration (ET0), differences between the two will indicate water stress with possible reduction of the potential yield. Cumulative water stress is indicated by the cumulative deviations of ETa from normal for different stages of the growing period.

The cumulative deviations of ETa are a measure of drought intensity, and to some extent drought impact. In addition, they can be carried over from one year to another, showing patterns of water deficit or surplus that may occur over longer time spans (Figure 7).

ETa-based indicators are useful for rapid identification of areas with severe drought problems. They can be easily spatialized where meteorological networks are adequate. In addition, in view of the strong correlations between NDVI and ETa, there have been successful attempts to derive ETa directly through remote sensing (e.g., Bastiaanssen 1995). Most important, in areas where

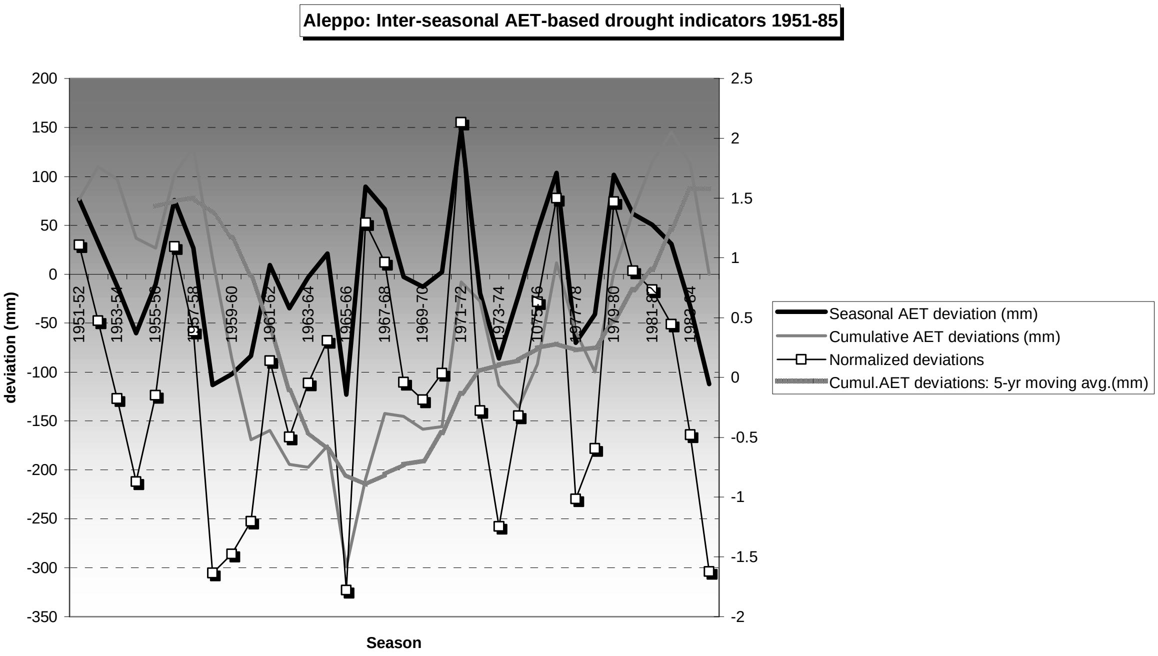


Figure 7. An example of the interseasonal drought indicator based on seasonally accumulated ETa deviations at Aleppo, Syria.

yields are mainly conditioned by limited water supply, as is the case--by definition--in most semiarid areas of the world, ETa is strongly correlated with crop yield (Figure 8).

For the purpose of crop yield monitoring and forecasting, the indicators obviously have to be crop specific. The best-known systems are the National Early Warning and Food Information Systems established with FAO assistance in many countries of Africa (FAO 1990). These systems use an agrometeorological forecasting model, based on the water balance, which calculates for each station of the network, on a 10-daily basis, a crop-specific water satisfaction index (WSI), which is responsive to the sensitivity of crops to water stress at different growth stages.

The WSI is a weighted measure of ETa, which can then be correlated with crop yield, as in Figure 8.

A more sophisticated approach is used by the MARS[10] Project of the Joint Research Center of the European Commission for monitoring agrometeorological conditions and forecasting yields of the major cereal, oil seed, and root or tuber crops of the European Union. The engine is the crop growth simulation model WOFOST (Supit et al. 1994), which includes a water balance submodel and is supplied with daily meteorological data obtained from all national meteorological services. It uses national soil maps and pedo-transfer functions to convert measured soil attributes, such as texture and structure, into water holding capacity, an essential parameter for site-specific water balances. The crop phenology and yield forecasts obtained from the physically based simulation model are validated through NDVI imagery and corrected with a yield trend function representing technology-related productivity increases. Validation of the final yield and production forecasts is through a network of statistical sampling sites (de Koning et al. 1993). To improve the estimates of crop areas, the feasibility of rapid assessment of crop area changes through high-resolution satellite imagery from a scattered sample of 100 mini-sites, which represent different agroecological and land use situations, is currently investigated. This system is currently being extended toward Eastern Europe and North Africa. For more details on the MARS project and project bulletins, see the relevant web pages.[11]

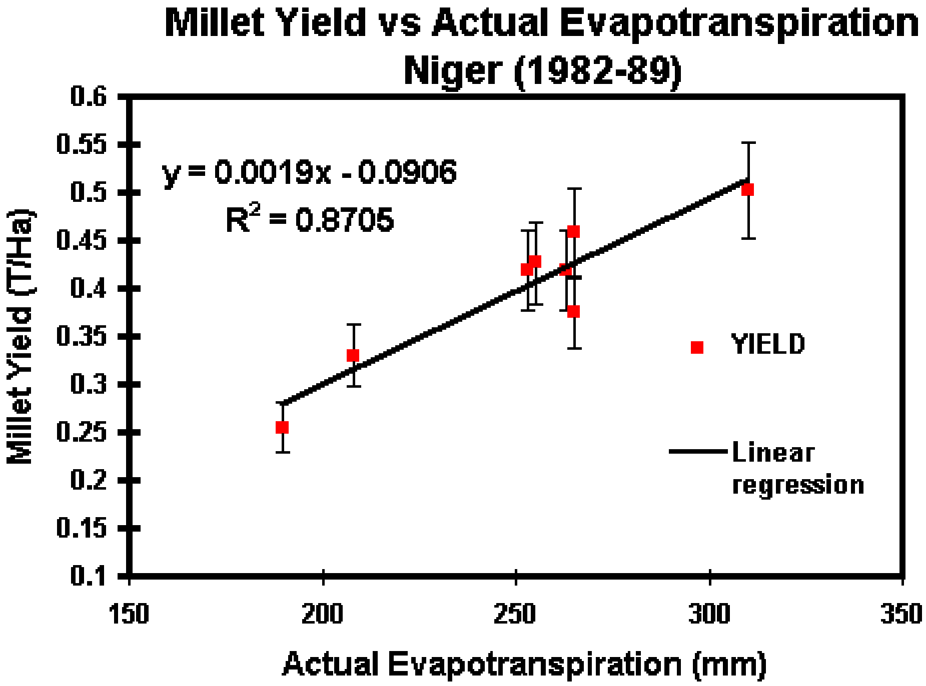


Figure 8. Example of relationship between crop yield and ETa (from Gommes et al. 1998).

Spatialization

In most countries of the region, the network for monitoring rainfall is adequate. Assessing the extent of drought on the basis of rainfall only is therefore not a problem. For other weather parameters, particularly temperature, sunshine, humidity, and wind, the number of measuring stations is insufficient. Since many countries are quite diverse in terms of landscapes and topography, temperature regimes will not be uniform and, in view of their effect on crop water demand, have to be taken into consideration when using water balance-based drought indicators.

Several statistical techniques are now available that make use of digital elevation models (DEM) in order to improve the spatialization of climatic parameters. In view of the strong linkages between climatic variables (especially temperature, but also rainfall, humidity, and sunshine) and topography, the most promising techniques for spatialization in climatology are multivariate approaches, since the latter permit the use of terrain variables as auxiliary variables in the interpolation process. In contrast to the climatic target variables themselves, which are only known for a limited number of sample points, terrain variables have the advantage of being known for all locations in between, which increases the precision of the interpolated climatic variables significantly. Co-kriging (e.g., Bogaert et al. 1995) and co-splining (e.g., Hutchinson and Corbett 1995) are methods that in most cases lead to excellent interpolations.

Another important tool for spatialization is remote sensing. Remote sensing has become a standard tool in most food security early warning systems, such as FEWS, GIEWS, and MARS. This is mostly the result of decreasing costs of satellite data products and image analysis tools, large-area coverage, and significant correlations between soil moisture status or biomass productivity and some parameters derived from spectral analysis (e.g., NDVI). The major role for remote sensing in these systems is to monitor changes in the edaphic factors. By its synoptic view and rapid refresh capability, remote sensing offers a unique ability to integrate the effects of changing weather, vegetation, soil, and land use. These changes can be monitored over different spatial and time scales. Especially the use of AVHRR imagery, with low spatial but high temporal resolution, in combination with higher-resolution imagery such as Landsat or SPOT, in representative sample areas, offers cost-effective prospects for monitoring drought and associated agricultural production deficits. A successor of AVHRR, the MODIS instrument on the Terra satellite launched in December 1999, will soon produce imagery with NDVI at 250 m resolution and other vegetation indices at 500 m or 1 km resolution.

Agroecological characterization is a very important support activity for drought early warning systems and is needed for both short-term and long-term drought management. The delineation of zones that are relatively homogeneous in terms of climatic conditions, soils, landscapes, water resources, and land use systems is required for establishing drought vulnerability profiles and drawing drought risk maps. These studies also allow to target new crops or cultivars to match climatic conditions where either drought evasion is possible or drought tolerance is required.

Agroecological zones are developed in a GIS approach, developing individual thematic layers, which are merged into gradually more integrated layers. The zones are then further characterized by overlaying new themes. The principle is illustrated in Figure 9.

Institutional Arrangements

Institutional arrangements may determine success or failure of drought early warning systems. The key characteristic of well-functioning early warning systems, whether for drought or food security, is that they are small but multidisciplinary and tightly integrated units. Of critical importance for the success of all early warning units is the free flow of information. This should send a strong signal to all institutions, which, by the very nature of droughts, have a key role in drought monitoring and management. In particular, meteorological services of the region are likely to come under public scrutiny if they appear to hamper the joint efforts required to combat drought through constraints on the provision of meteorological data.

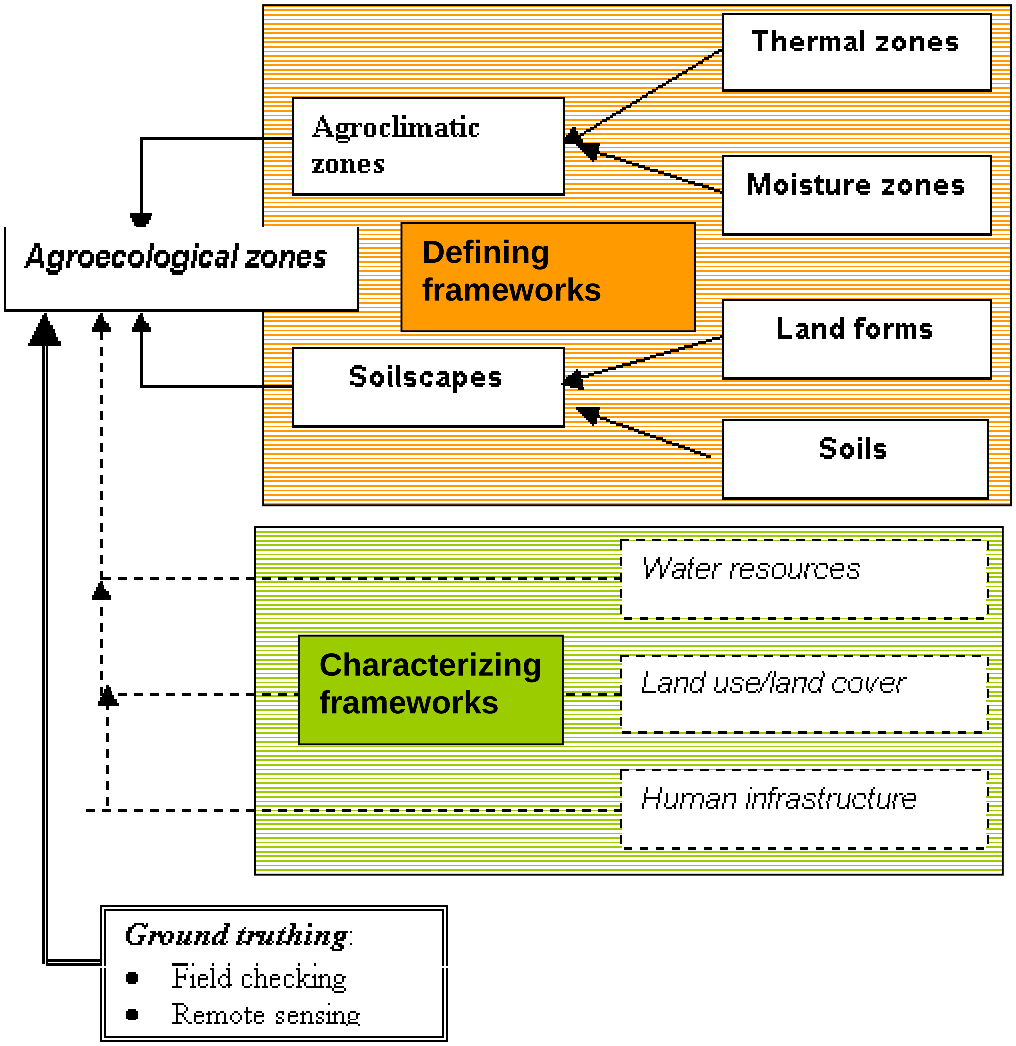


Figure 9. Integration of thematic layers into agroecological zones.

In drought-prone countries, a central drought management unit needs to be established, with a legal status and mandate and a small multidisciplinary core staff. This structure would be most effective if housed in a coordinating ministry, such as a prime minister's or president's office, or a planning ministry, rather than a line ministry. This way the drought coordinating body would have access to the multidisciplinary manpower and information sources in other ministries, to deal with any emergency, as droughts get worse, or for developing drought management plans. Such a unit would also hold responsibility for developing policy to facilitate drought mitigation both in the short term and long term.

Under the general supervision of the central drought management unit, but not necessarily in the same ministry, a drought early warning unit needs to be established with a more technical character. This unit will compile and interpret all data sources to monitor drought extent and impact, and report through regular or special bulletins to the central drought management unit. The experience of the described food security information systems, although not fully transferable in a drought and different economic context, may be useful to develop the specifications for national drought early warning systems in the North Africa/West Asia region.

It is encouraging that the government of Morocco has recently established an entity for drought monitoring, very much in line with the above principles. The "Observatoire pour le Suivi de la Sécheresse"[12] is a permanent coordinating body with a legal status and mandate, and with a small multidisciplinary core staff, drawn from different ministries. Drawing inspiration from the international monitoring system, which successfully integrates multiscale, multi-institutional and multidisciplinary data sources, this coordinating unit is at the apex of a "virtual" structure composed of technical experts from different government administrations, dealing with different aspects of drought management through technical committees and working groups. The technical committees are responsible for monitoring and prediction of harvests, monitoring and impact evaluation of drought alleviation programs, and strategy development for long-term drought mitigation. One of the major tasks for the Monitoring Committee will be to set up a drought early warning system, which, on the basis of multiscale and multidisciplinary indicators, will monitor the evolution of agricultural, meteorological, hydrological, and socioeconomic drought.[13]

The idea of the *Observatoire* as an integrated system for *drought management*, rather than drought monitoring, is a useful model for the other countries of the region and, if successful, is likely to be reproduced.

Footnotes

[1] Food and Agriculture Organization of the United Nations.
[2] Global Information and Early Warning System on Food and Agriculture.
[3] URL: http://www.fao.org/WAICENT/faoinfo/economic/giews/english/giewse.htm.
[4] Source: http://www.meteor.gov.tr/webler/hidro/hidromaster.htm.
[5] USAID Famine Early Warning System. See http://www.info.usaid.gov/fews.
[6] See "Predicting drought," on the NDMC website at http://enso.unl.edu/ndmc/enigma/predict.htm.
[7] For details, see http://www-pcmdi.llnl.gov/modeldoc/amip/13cnrm_b.html.
[8] For details, see http://enso.unl.edu/ndmc/enigma/indices.htm.
[9] An in-depth analysis of the SPI can be found at http://enso.unl.edu/ndmc/watch/spicurnt.htm.
[10] Monitoring Agriculture with Remote Sensing.
[11] See http://mars.aris.sai.jrc.it/stats/bulletin/.
[12] Observatory for Drought Monitoring.
[13] Personal communication by Dr. T. Ameziane, Institut Agronomique et Vétérinaire, Hassan II, Morocco.

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