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Drought Monitoring and Modelling

Kuraklık İzleme ve Modelleme

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SUMMARY

Unprecedented scientific and technological developments during the last century have brought new problems concerning the survival of living organisms on the earth. This century will have to support and sustain especially living organisms including human race with its ever increasing population, improved health services and wealth greater than ever. Recently, public is becoming more aware of the natural hazards that destruct many human societies at different parts of the world. The parlance of 1global change" is advocated at every aspect of the life equally in the social, economical, political, military and many other domains, but physical global changes such as the changes in the climate and conventional way of life brings extra overburdens to human population. Among the natural hazards perhaps, the ones that are related to water surplus or deficit are more risky totally to human societies than any of the geological hazards as earthquakes, volcanic eruptions and landslides. The forces of nature become more treatful and bring the human population under more severe risk dangers as the world population grows with more materialistic abilities, and as the existing and expanding environments try to accommodate with its limited sources these societies. Especially, land and more precious water sources are under heavy burdens due to demographic and social trends that show continuous increase with time.

INTRODUCTION

Modern times have brought another sort of environmental risk on human lives and properties due to "man-made" threats. Among these are industrial explosions, transport accidents and many other technological threats. Last but not the least, natural hazards find their swift way in the communication channels and press media with high speed of spread especially throughout the world on television screens. Presently, everywhere in the world natural hazards may appear unexpectedly t5han ever and consequently there are the following questions which are interests of scientists, administrators, citizens and world. By considering the increase in the natural hazards in recent decades the following questions are among the most naive opens to ask. Is the world as a whole or in many regions becoming more dangerous than before? Is there an increase in the risk of a human society being more vulnerable to certain processes? Are these genuinely natural or are there human-made triggers for the initiation of the so called natural events? Are the newer technologies increases or decrease the appearance, magnitude and frequency of the natural hazards? Is it possible to eliminate completely the hazardous effects of the natural extreme phenomena? Since, it is not possible completely to avoid the appearance of natural hazards then is it possible to take necessary measures against them with certain risk expectations? What are the best means of mitigating disasters? Although, there are tremendous investments against the reduction of destructive effects of these hazards, why the losses continue to rise? How can the human manage the water resources temporal and spatial availabilities in order to combat the most survival needs of human population? Are there enough monitoring investments and thereafter models to control the possible destructive occurrences of the natural hazards? What are the missings or defacts that did not give way to have the most successful model and management program in combating the natural events? Are the natural events that we are told natural by press media, really natural or natural coupled with human inducements? Is it better to take the necessary precautions against the natural hazards for an irrational settlement of human population or better to change the settlement locations to very less hazard prone locations? Are the hazards to be tamed by engineering and administrative calculations and regulations or they should rather be thought attached with societies? The sequence of similar questions can be lengthened unendingly, but it is important to identify the most significant ones and accordingly try to reduce their hazards. Unfortunately, clear answers to these questions remain rather fuzzy and elusive. Broad-based natural hazard research and investigations did not begin until almost the middle of the twentieth century.

Most often starting from 1970s onward, most natural events have been foreseen by hydrologists and engineers as extreme value calculations and consequent construction of physical structures in order to withstand the hazardous effects. However, recently sociologists, administrators and government offices started to assess the natural hazards in the context of preparedness and collective human behaviour at times of community crisis. During the 1070s extreme natural events became more prominent. For example, the prolonged Asahelian drought in Africa, the failures of the Pruvian anchovy harvest, the 1975-1976 drought in north-west Europe and the severe North American winters of 1976-1977 and 1978-1979 exposed the vulnerability of many countries, including advanced nations, to climate variability. However, in 1980s a new emphasis was given to the relationship between under-development and hazard impact in the Third World, especially to the extent to which socio-economic factors, such as economic dependency and a colonial legacy, exacerbates the effects of geophysical events (Smith, 2001; Şen,).

DROUGHT DEFINITIONS

Roughly droughts are defined as the temporary reduction in the rainfall and soil moisture amounts and it is related to the climatology of the region. Especially dry climates are prone to drought effects due the soil moisture deficiency and high variability in the rainfall occurrences as well as amounts. Droughts are among the continuous threats to the mankind in the future. Apart from the famine they cause immigrations and hence more demand on water resources in migrated new areas. They curtail dramatically water supplies and food productions by damaging agricultural systems, forests, wildlife and especially soil. Unfortunately, there is no universal panacea and each country might experience drought effect some time in future and accordingly in addition to general drought curbing precautions each country has its own drought combat program depending on the climatological, geographical and hydrological features. Water shortages are the primary cause and a manifestation of drought anywhere in the world. Especially in arid regions of the world, the drought duration seems endless. Vital water resources in the world are limited and their temporal and spatial distributions are very heterogeneous. The strive for economical growth leads to population increase and hence increasing reliance on water resources and thereby increase in the vulnerability to droughts. Droughts occur in any type of climate, arid or humid. Drought occurrences have extensive time and areal coverages and accordingly among their quantitative labels are the drought duration, intensity, areal coverage and vulnerability. In the agricultural sense, drought is considered as a moisture deficiency that has serious, adverse effects on a community which results generally in food production reduction.

There are many and different definitions of droughts in the literature. However, it is defined generally as an extended period of rainfall deficit during which agricultural harvests are severely curtailed. The most important effect of climate change on water resources will be a great increase in the overall uncertainty associated with the management and supply of fresh water resources. Significant hydrological components such as storms, rainfall, streamflow, soil moisture and evaporation all effecting the agricultural activities, are substantially random in their behaviour and accordingly any hydrologist or agriculturalist will regard them in terms of uncertainty scientific methodologies, namely, statistics, probability and at large stochastics. All these scientific approaches provide future estimations on the basis that the surrounding environmental effects and the climatic change are all stationary. This means that the pattern of the local environmental and global climatic changes in the recent past will repeat in the near future. As will be presented in a later section of this chapter, it is possible to quantify the uncertainties with few formulations under restrictive assumptions. It must not be forgotten at this stage that, certainly the future pattern of the climatic change and its consequences will not look like the past behaviours. It is, therefore, necessary to try and manage our water supply sources with more care about the undesirable extreme cases in the future. This brings into the scene the concept of risk and management under the risky environment.

Drought definitions are classified as conceptual, i.e., relatively vague (fuzzy) and operational which is meant to provide specific guidance on aspects of onset, severity and termination. The latter descriptions are among the objective quantities that are frequently asked about any drought. These are when is the starting time of drought? How severe is the drought? And when is the termination time of the drought? In fact, the time difference between the termination and starting instances shows the duration of drought.

Although many areas were prone to drought risks all over the world, unfortunately the drought existence and appearance have been vague, imprecise, uncertain and most of the time fuzzy not only for the common people but also for the experts in the area. It is, therefore, difficult to find a unique definition for droughts and consequently the current definitions are rather based on expert and professional concepts. In order to alleviate the case, most often droughts are classified right from the beginning according to their attachment of economic consequences and physical causes. Even though droughts inflict economic losses but they are social phenomena as well.

WATER RELATED HAZARDS

The origins of any type of drought lie in regional or global climate variations that produce precipitation far shorter than commonly expected levels.

DRY PERIODS AND DROUGHTS

Dryness is a common feature in the desertic and steepic areas of the world where there are water deficits throughout of many years and centuries. The environmental life in such areas are adopted to water scarcity and therefore only water deficit bearing plants and animals can survive in these areas. Great deserts of the world are areas of dryness and aridity. The duration of dryness, steppe and desertic conditions are time continuous and have a real extensiveness. The desertic areas occur in the northern and southern flanks of the tropical regions around the equator.

Droughts, on the other hand, are discontinuous in time and areal extent and hence differ from other natural environmental hazards because they occur in a short time and most suddenly in many cases. However, droughts have a 1creeping1 feature which is very gradual and hence their developments are slow and have prolonged existence, sometimes over many years. Droughts are not confined with local topographic features or geological structures and they are more extensive over large areas. In practice, it is most often very difficult and almost impossible to tell the beginning of a drought and hence their distinctions from human induced desertification. Depending on the development of water resources system and distribution droughts vary greatly depending on the degree of development. Attached to any drought event especially in the less developed regions of the world is the food insufficiency due to the restrictive agricultural activities and consequent famine-related death in the human and living organism populations. Although famine is the most serious outcome of drought but it is not always directly related to drought. In areas of scarce water resources and hence limited agricultural products and consequent insufficient food stokes malnutrition is most widely spread disease in the world. As will be explained later in this chapter both famine and malnutrition are related to agricultural droughts. Among the main causes of drought are the climate effects but these are not the only ones. Mismanagement of water resources, water resources pollution, acid rains, overexploitation and many other human made effects are also effective in the extent, appearance and severity of droughts.

DROUGHT TYPES

Depending on the main agency of water related activities, droughts can be classified into different types. As shown in Figure 2 these are meteorological, hydrological, agricultural and social droughts. Of course, these are the types of droughts that are water dependent. Hence, the main agency is the water availability and its feeding environment. In general, meteorological drought is defined objectively by considering the rainfall temporal variations in an area. Since, the rainfall is a meteorological element and its generation depends at the background on the hydrological cycle and in the foreground the formation of clouds and the condensation of water vapour in the clouds they can be considered as the atmospherically related hazards. Rainfall deficit is the indication of meteorological drought. The rainfall deficit depends on many basis such as natural groundwater recharge, soil moisture sustenance, plant life support and surface flow generation. In fact, meteorological droughts are the initiators of other droughts and therefore they have the least disaster potential. For instance, rainfall does not supply water to plants but the soil fed by rainfall does. Hence, even during rainfall deficit periods the soil fed by previous wet periods will supply plant water for use. Likewise, rainfall does not supply water directly for irrigation, domestic or industrial use. Natural water sources are not rainfalls but rivers, lakes and groundwater. This implies that, in the case of insufficient rainfall, the demand on water can be obtained from other sources such as the surface flow, lakes or groundwater reservoirs. The meteorological drought duration is also location dependent concept because in Bali 6-day duration of rainless period means drought whereas in many desertic areas as for the Rub-El-Khali in Saudi Arabia 2 about 2 years of rainless duration implies meteorological drought. In such a definition of meteorological drought zero rainfall level is considered as a base level. However, by considering some other amounts, say, 10mm as a basis, a meteorological drought does not appear as long as the rainfall amount is above this base level.

Meteorological droughts result from the stagnation or persistence of atmospheric high-pressure system over a region which is typified by subsidence, clear skies and low temperatures. Such an appearance in a region prevents normal atmospheric sequence of wet and dry weather progression by the general atmospheric circulation.

Another definition of drought index as used commonly in USA is the Palmer Drought Severity Index, which considers the soil moisture budgeting based on two meteorological variables, namely, precipitation and temperature over a given area and basic time duration of month or year.

Hydrological drought is more related to human water demand and it appears whenever a marked reduction becomes appreciable in natural streamflow or groundwater levels, plus the depletion of water stored in dams and lakes for water supply. If water is supplied from these reservoirs then the hydrological drought becomes more important than the meteorological one. Hence, hydrological droughts are very important and significant for urban areas or industrialized regions as well as for agricultural activities. The main impact of hydrological droughts is on water resource systems. Hence, pollution of water resources also emphasizes the hydrological drought.

Most often the definition of hydrological drought is dependent on surface water availability but a base level is necessary for the objective definition of these droughts. For this purpose, there are many criteria either based on the water demand, engineering design discharge or statistical exceedance levels. For instance, in the case of water supply from a streamflow without any reservoir construction for water impoundment, the discharge continuity line is taken into consideration for the determination of basic level as 95 %. The discharge level is shown in Figure 3 as the percentage of the discharge equalled or exceeded versus the discharge. By definition, droughty flows are river discharges below this level, when water abstraction have to be restricted or when effluent discharges have to be reduced, unless other additional sources can be found.

Hydrological droughts are related to the agricultural droughts by its effects on irrigation systems dependent on surface water and on river water quality which is likely to be deteriorating with reduced levels of dissolved oxygen and the discharge of sediment-laden bottom water from reservoir storage. The standard solution for hydrological drought effects are the construction of surface or subsurface dams in addition to the transmission lines for water distribution to drought stricken areas.

AGRICULTURAL DROUGHTS

Agriculture is a general plant growing activities for the sustenance and survival of human population on the earth. In their growing epochs, plants need combination of solar energy from the sun, carbon dioxide from the atmosphere and water from the soil moisture. Today, two-thirds of the fresh water resources are used for the irrigation and consequent agricultural activities all over the world. Due to the population growth of the world more water will be needed in the future for growing food needs. On the one hand rising economic and environmental problems will not give way for the increase of irrigable land area, and on the other growing population will give rise extra pressure on the agricultural productions. In addition to these problems, occurrence of even slight drought conditions in an agricultural area will pronounce its hazardous effects in large scales.

Since civilization first developed urban-agricultural systems, they have been plagued by droughts and in some cases consequent famines. Agricultural drought is very important because of its implications for food, malnutrition and consequently possible femine. The appreciation of agricultural droughts are felt in agricultural societies of the world including well developed countries and in the societies where many people earn their livelihoods from the agricultural production as well as activities. Plants need water in the soil for their growth and shortage in this water supply result in an agricultural drought. Such water shortages may appear both in arable and postural soils of the world. It is possible to define agricultural drought if the soil moisture is insufficient to maintain average crop growth and yields. Hence, the direct assessment of agricultural droughts is possible by monitoring the soil moisture in agricultural lands but most often instead the water balance approached as the Palmer Drought Severity Index are used for practical purposes. The implications of agricultural droughts appear in many diverse sectors such as in the local and regional economy, social food self-sufficiency and nutrition. Any reduction in the crops harvest is one of the indicators of the agricultural drought appearance in an area. For instance, wheat production in any region and year compared to the average crop product for the 5 previous years shows the existence of agricultural drought. Appearance of severe agricultural drought affects livestock as well, and their recovery is not possible within few years but on the average 5 years or more. During this after agricultural drought period the society must bear the aftereffects of the drought during subsequent years.

Extreme forms of agricultural droughts might lead to famine and mass deaths from starvation due to food insufficiency. In general, famine is defined as protracted total shortage of food' in a restricted geographical area, causing widespread disease and death from starvation (Dando, 1980). Famine is not a geographical phenomenon but rather a cultural phenomenon. In many developed countries severe agricultural droughts appear but with no deaths as a result of starvation because there are stores of extra food supply from the previous years or from the adjacent areas without simultaneous drought impact. Although famines due to different effects such as the war, social disturbance, infective diseases, industrial exploitation, etc. Have occurred during the long history of human, but today it tends to be associated with semi-arid areas of subsistence, or near subsistence, agriculture where crop failure has resulted from droughts.

DROUGHT MITIGATION

Solutions to agricultural drought epochs are possible by expanding the irrigation water facilities and especially by increasing the efficiency of existing systems, so that crops can be grown with less water requirements. In many irrigation networks, less than half the water actually benefits crops, and the rest is lost through seepage from unlined canals, evaporation and runoff from poorly applied water, and poor management that falls to deliver water to crops at the right time and in suitable quantities (Gleick, 1993). Further development of the irrigation projects are not without problems and if necessary precautions and measures are not taken timely, such developments may lead to other irrigation problems such as the waterlogged and salinized lands, groundwater pollution and hence reduction in the use of this water source, and destruction of aquatic habitats.

The groundwater resources are the major water reservoirs for irrigation and hence agricultural production in many arid lands of the world. They are the most extensive sources and their quality is very suitable for the irrigation purposes. Therefore, in the long run in order to combat agricultural droughts more than the surface water supplies, the subsurface water supplies are more significant. Even in the Arabian deserts, local agricultural production, today, is possible with the help of well technology, to abstract deep groundwater and by radial sprinkles, to grow crops for the local and regional uses. Unfortunately, today even in the developed countries such as the USA, the groundwater abstraction rates for irrigation exceeds the natural recharge and due to this over pumping the groundwater levels decrease several meters per year. This will also increase the rising cost of the groundwater.

After 1970s, there is a slowing rate of increase in the irrigateable land area in the world. Due to either pollution or over-exploitation of local and nearby water resources for irrigation, there appears a new pressure to transfer water away from the agricultural areas. On the other hand, future threats such as global climatic change all complicate the rational management of agriculture. Another significant mitigation towards the droughts is the maximum benefit from the rainfall harvesting or rainfed farming.

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