CASE STUDIES

Sustainable Development of Agriculture and Food systems with regard to Water

Carlos Gregorio Hernández Díaz-Ambrona,
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SUSTAINABLE DEVELOPMENT OF AGRICULTURE AND FOOD SYSTEMS WITH REGARD TO WATER

Carlos Gregorio Hernández Díaz-Ambrona, **Esperanza Arnés Prieto** and **Omar Marín González** - Universidad Politécnica de Madrid.

“Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, ***including food****, clothing, housing and medical care and necessary social services, and the right to security in the event of unemployment, sickness, disability, widowhood, old age or other lack of livelihood in circumstances beyond his control.”*

Article 25 - Universal Declaration of Human Rights

INDEX

1. Introduction

The biggest challenges related to agriculture are guaranteeing that the food supply keeps up with current population growth and improving the diet. It is projected that by 2050, the world's population will rise to 9 billion. According to the Food and Agriculture Organization of the United Nations (FAO), food production will have to increase by 50% to 70% to ensure food needs are met. Also, the United Nations estimates that the need for water will increase by 30% to cover food demand. According to the Organization for Economic Co-operation and Development (OECD) environmental indicators for 2050 (OECD, 2012), there will have to be an increase in the water supply to avoid situations of food insecurity. However, the OECD projection estimates that 40% of the population will live in basins with a high level of water stress.

The Cooperation Group on Agricultural Systems (AgSystems) is an interdepartmental consortium of university researchers from the Technical University of Madrid (Spain). AgSystems' main area of research is the study of management and productivity of agricultural systems and their relation to the environment in terms of sustainability and resilience. The main target of the group is the design of new or adapted strategies for sustainable/resilience production systems under current and future conditions. To this end, AgSystems supports research projects that combine field experiments and the generation of crop systems simulation models linked to Decision Support Systems Simulation models. The main research lines are:

- Water and nitrogen management in agricultural systems
- Modelling of crop and cropping systems
- Impact of climate change

Current projects to support this contribution are:

- Rural Community Program of the Technical University of Madrid and related projects (2006- present).

- AGRISOST, Sustainable agricultural systems: Management of carbon, nitrogen and water for production and quality optimization (S2013/ABI-2717), BOCAM 2014[1](2014-2017).

[1] Website: http://www.madrimasd.org/programas/web/agrisost

- MACSUR, Modelling European Agriculture with Climate Change for Food Security. (2012-2015) FACCE JPI. European Commission. VII Framework Program.

1.1. Disciplines covered

Future sustainable and resilience agriculture will have to meet the following challenges (Diaz-Ambrona and Maletta, 2014): 1) Agriculture must guarantee food security with regard to quantity, quality, price, and accessibility. Agricultural products must be priced appropriately; prices must be high enough to ensure the standard of living of farmers, yet be affordable to everyone, especially to people in urban areas. 2) It is necessary to improve the systems of production in remote areas (which is important because 50% of the world's poor are farmers), improving traditional farming techniques while preserving local, socially and culturally accepted varieties and crop systems. Marketable surpluses must be generated while increasing local trade of products that comprise the basic shopping basket. 3) Variability of production must be reduced by improving production techniques and increasing the diversity of crops through investment in agricultural research. Environmental risks (droughts, floods, freezing) must be prevented, and the effects of global environmental problems such as climate change in the medium and long term must be assessed. 4) It must preserve the environment, protect the nutritional integrity of the soil, reduce runoff to adjacent water bodies, protect biodiversity through diversification of crops and reduce heavy chemicals use.

Water is one of the most prized land elements for life. Life arises from and moves around water. Plant growth depends on soil water availability. Plants are very efficient conductors of water; water penetrates from the soil through their roots and stems, then through their leaves out into the atmosphere, via transpiration. Crops need large amounts of water. Only 6.1% of the renewable fresh water supply is accessible runoff. Most water is found in the oceans (97.4%) and in ice, polar lands, and glaciers (2%). Freshwater distribution is irregular; some areas, such as the Amazon basin, have large quantities of water with minimal human usage, whereas others, such as Saharan Africa, have very little availability. Agricultural water requirements are calculated by estimating crop evapotranspiration needs. Transpiration water is linearly correlated with crop biomass. For example, the amount of water needed to produce a kilogram of grain under appropriate conditions varies from 1000 L for rice to 500 L for maize (Hernández and Marín, 2012). Water used is important for both rainfed and irrigated crops. Regulated water resources are focused as a service for irrigating land; it is for this reason that irrigation uses 70% of regulated water globally. Transpired water always returns to the atmosphere. A person needs to drink at least 2 L of freshwater per day, moreover a person needs 2000 L of water that is embedded or embodied in a balanced diet (which corresponds to the water used in food production). Improvements in yields of both rainfed and irrigated crops have increased water usage. According to Brauman et al. (2013), irrigated cropland and the demand for water will increase significantly by 2050.

1.2. Learning outcomes

Research question: How does weather variability impact farming? Could agricultural water management innovations help to reduce food insecurity and improve sustainable agriculture?

- Know agricultural water demand by crops,
- Weather variability impact on farming,
- Designing sustainable cropping systems to reduce poverty and increased food security in rural areas,
- Impact of new agricultural water management innovations in smallholder agriculture

Learning outcomes are expected:

- First learning outcome: Crops need large quantities of water
- Second learning outcome: Water availability is the main cause of annual or interannual variability in food production

1.3. Activities

The two activities of the case studies are: 1) Class activity and 2) Homework.
This case study is:

- Problem resolution
- Individual work
- Debate in the classroom

Tools and accesses needed:

- Computer
- Spreadsheet application
- Internet access

2. Description of the context

The FAO (FAO, 2007) estimates the minimum amount of water for poverty in 700 m^3 of total available water per person per year. Taking into account the nutritional standard unit of 500 kg of cereal per person, the amount of water needed to grow rice and maize is 500 m^3 and 250 m^3 per person per year, respectively. For example, in Egypt, a country heavily reliant on irrigation, the forecast is that by 2025 the available water per capita will decrease to 500 m^3 per year (NWRP, National Water Resources Plan, 2014). It is well-documented that irrigation contributes to the alleviation of hunger and poverty in Asia and Africa, although success is not reached in all cases (García-Bolaños et al., 2011; Borgia et al., 2013). These values show that agriculture is the activity for which most water is needed. Water is the main renewable resource required for cropping. Moreover, not only is a certain amount of water required, but water should be available in the quantity needed at key points in the crop cycle. Managing the availability of both, rainfall and irrigation water, is critical for successful agriculture.

Efficiency in the use of water depends on physiologic factors of crop species, environment, and crop management. Efficiency is greater in plants that have a photosynthetic mechanism called C4, including crops such as maize, sorghum, and sugarcane. These crops are adapted to tropical and subtropical climates and, therefore, do not grow in environments with average temperatures below 10 °C, as compared with C3 species such as wheat and barley which can grow in these environments. In addition, the photosynthetic mechanism called CAM (Crassulacean acid metabolism) common on plants among desert succulents (*Cactaceae*) or among tropical forest epiphytes (*Bromeliaceae*) shows the highest water efficiency, but with low net growth. Meanwhile, intensive growing in greenhouses allows control of climate-related variables that affect crop development and raises the efficiency of water use to the maximum due to high humidity inside the greenhouse. For example, in the case of tomatoes and beans, water use efficiency is almost 3.5 times greater in a greenhouse than for outdoor cultivation. In addition, irrigation allows higher productivity and decreases yield variability, therefore the risk of having years with famine or lack of a food supply is reduced.

Irrigation has contributed to yield stabilization and an increase in productivity, but water resources must be managed properly. In some regions of Asia and the Middle East, the ground water table is falling quickly because of a lack of water regulation and high demographic pressure (Hefny, 2012). For Hefny (2012), the key factors causing water/food-induced conflicts are water scarcity and population growth, mismanagement of water, problems in transboundary river basin management, limited information on water resource availability, water policy overlaps, water quality degradation and pollution, structural imbalance, problems with management authorities, limited awareness of water issues, a slow transfer of technology, a shortage of capacity building and institutional development, inadequate stakeholder participation, a shortage of available funds, and poor public awareness programmes. Finally, the growing meat demand is linked to an increase in grain production; it is estimated that 1 billion tonnes of grain is dedicated to feed animals annually, but crop and livestock are complementary, half of world's food comes from mixed farms (Eisler et al., 2013). The authors discuss the steps to sustainable livestock management that focus on ruminants. Ruminants eat high fibre plants that are unsuitable for human, pasture management and improvement can help achieve sustainable livestock production (Eisler et al., 2013).

2.1. DROUGHT AND WATER STRESS

Drought is a natural hazard that occurs as a result of lower levels of precipitation or available water for economic activities than is considered normal for a particular location. Drought is one of the major weather related disasters (Horion et al., 2012). Drought must be considered a relative condition and must be considered as part of the dry season of a climatic region. Also, water stress is a perennial challenge in most arid and semi-arid regions of the world. Areas such as the semi-arid Sahel, the Horn of Africa and Southern Africa, have high dependence on groundwater[2].

There are four approaches to measuring drought: meteorological, hydrological, agricultural, and socioeconomic (Wilhite and Glantz, 1985):

Meteorological drought is usually defined as the lack of precipitation over a long period compared with the normal distribution. It is based on the degree of dryness and the duration of the dry period.

Hydrological drought is related to the effects of periods of precipitation (including snowfall) shortfalls on surface or subsurface water supply. It reduces the amount of water in streamflow, groundwater, reservoir and lakes. Hydrological drought reduces the amount of water available for irrigation.

Agricultural drought links meteorological or hydrological drought to agricultural impacts. It is produced when evapotranspiration water demand is higher than available water from soil, precipitation and/or irrigation. Crop water demand depends on prevailing weather conditions, biological characteristics of the specific plant, its stage of growth (from emergence to maturity), and soil properties.

Socioeconomic drought is associated with the supply and demand of economic goods or services as consequence of meteorological, hydrological, or agricultural drought.

[2] http://www.undp.org/content/dam/undp/library/corporate/HDR/Africa%20HDR/ UNDP-Africa%20HDR-2012-EN.pdf

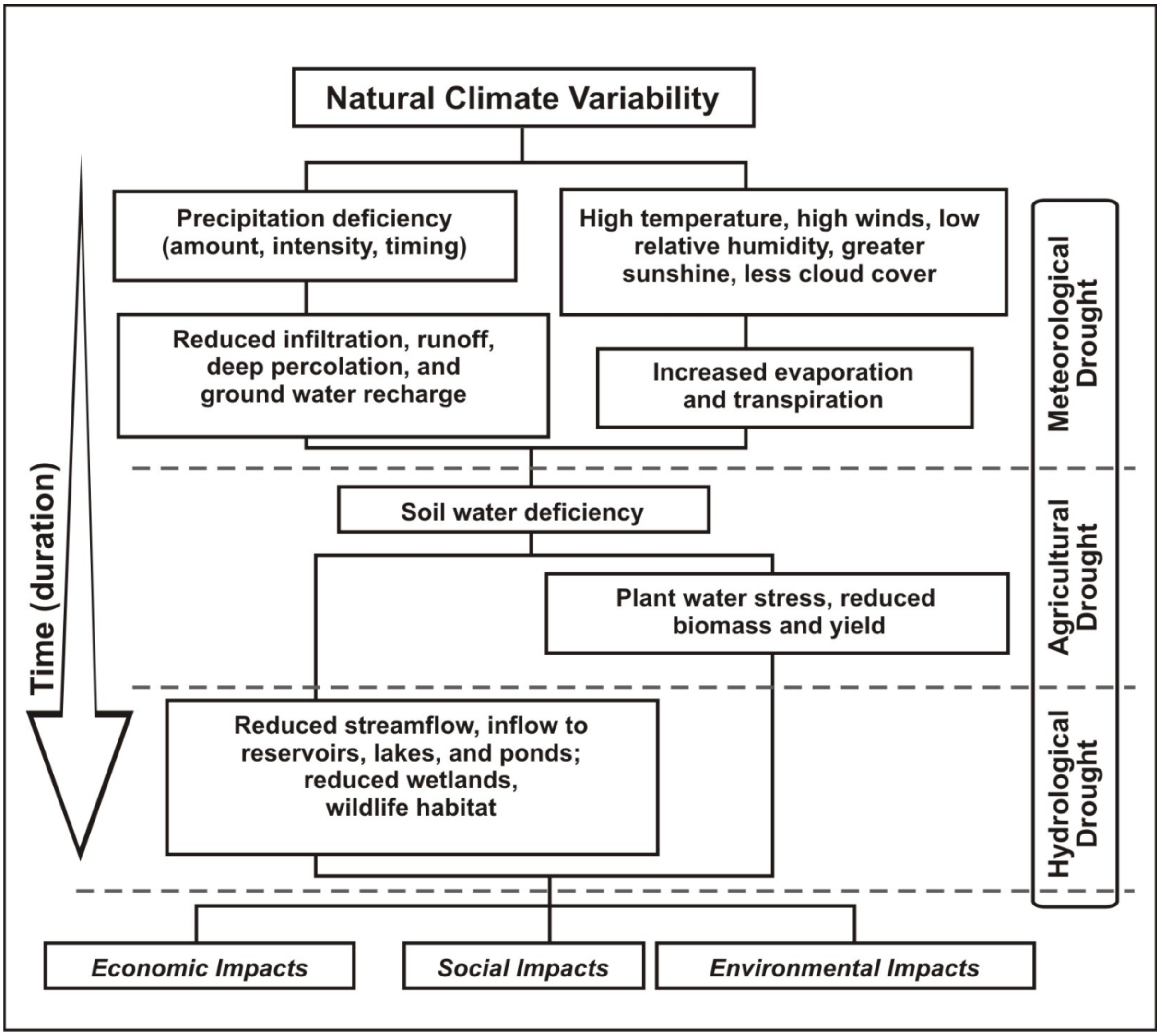

Figure 1 *Sequence of occurrence and impacts for meteorological, agricultural, and hydrological droughts. All droughts originate from a deficiency of precipitation or meteorological drought but other types of drought and impacts cascade from this deficiency. Source: National Drought Mitigation Center.*

Drought is a devastating event in developing countries (Table 1). For example (Sun and Areikat, 2013): in Morocco, half of the sheep flock died due to droughts in 1945 and 25% of the cattle and 39% of the sheep died or were sold prematurely in 1981–82; in Syria, 3 million sheep (25% percent of the flocks) died or had to be slaughtered during the 1983–84 drought; four severe droughts from 2000 to 2011 left 2-3 million people in extreme poverty, and wiped out 80-85% of herd stock; in Jordan, at least 70% of the camel herd died in a major drought between 1958 and 1962 . Drought can lead to food shortage if the crops in the growth season do not get enough water for their growth, this might lead to a number of severe social and economic problems related to a shortage of food and rising food prices. For the IPCC (Intergovernmental Panel on Climate Change), West Asia and North Africa have probably had less rainfall (up to 50% of the average for the period 1980-1999) in the last 20 years of this century compared to 1980-1999 (Contribution of Working Group I to the Fourth Assessment Report).

Table 1 *Drought disasters sorted by continent from 1900 to 2011. Source: Horion et al. 2012.*

Region	Number of events	Number of death	Total affected persons	Economic damage (000 USD)
Africa	269	844,143	317,936,829	5,419,593
Asia	147	9,663,389	1,666,286,029	33,823,425
Europe	38	1,200,002	15,482,969	21,461,309
Latin America and Caribbean	109	77	65,078,841	8,866,139
North America	14	0	55,000	11,945,000
Oceania	19	660	8,027,635	10,703,000
World	596	11,708,271	2,072,867,303	92,218,466

2.2. Drought Monitoring Tools

Drought indicators based on climate data and remote sensing products are at present the best available tools for monitoring drought (Zargar et al., 2011):

Rainy and Dry Days: Based on precipitation analysis with observed data from weather station, the relationship of rain/dry days can be calculated. Rainy days are considered to occur if rainfall is higher than 1 L/m^2 for two intervals of time: seven days or 30 days:
Maximum Consecutive Dry Days, Number of Rain Days and Number of Days Since Last Rain. The methodology (following National Drought Mitigation Center, USA): for calculation of the Maximum Consecutive Dry Days: the number of days that meet a threshold criteria (i.e. null rainfall) are counted and the largest consecutive count of days, regardless of when in the interval that count occurred, is shown as the "Maximum Consecutive Dry Days". For the number of rainy days, the total number of days that meet the criteria is summed for the product interval (week or month). Finally, for the Number of Days Since Last Rain, the most recent consecutive string of days that meet the threshold criteria is summed.

Standardized Precipitation Index (SPI): is based only on precipitation[3]; it is effective in analysing wet periods/cycles and dry periods/cycles. If possible, one needs at least 20-30 years of monthly values, although 50-60 years are optimal and preferred. The index can be calculated with shorter data series, but this affects the confidence of results. The Standardized Precipitation Index is based on the probability of precipitation for any time-scale and is then transformed into an index.

Drought Impact Reporter: The Drought Impact Reporter is an interactive web-based mapping tool designed to compile and display impact information from a variety of sources such as media, government agencies, and the public. Anyone is allowed to submit a drought impact, but there is a web moderator, and the moderator can request additional information as/when needed. It is operated in USA[4] and is a social and collaborative indicator.

Vegetation Drought Response Index (VegDRI): It is a bi-weekly index produced from remote sensing data using satellite-based observations. Vegetation Drought Response Index uses the Percent Average Seasonal Greenness (PASG) and Start of Season Anomaly (SOSA) variables. Both variables are calculated from the normalized difference vegetation index (NDVI) data acquired by NOAA's Advanced Very High Resolution Radiometer (AVHRR). Climate-related variables incorporated into VegDRI include the Palmer Drought Severity Index (PDSI) and the Standardized Precipitation Index (SPI). Information about soils, land cover, land use, and the ecological setting are incorporated into VegDRI, because the climate-vegetation response can vary depending on these different environmental characteristics[5].

Crop water stress index: This is the most used index to quantify crop water stress in a field. It is based on canopy surface temperature. Temperature in plants is regulated through transpiration. The crop water stress index has two baselines: the non-water-stressed baseline, which represents a fully watered crop and maximum plant transpiration; and the maximum stressed baseline, which corresponds to a non-transpiring crop with fully closed stomata (Yuan et al., 2004).

Regional networks on assessing and monitoring drought:

Europe

- Drought Management Centre for South-Eastern Europe (DMCSEE) http://www.dmcsee.org/

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[3] http://www.wamis.org/agm/pubs/SPI/WMO_1090_EN.pdf
[4] http://public.droughtreporter.unl.edu/submitreport/
[5] http://vegdri.unl.edu/

- European Drought Centre (EDC) http://www.geo.uio.no/edc/
- European Drought Observatory (EDO) http://edo.jrc.ec.europa.eu/

Africa

- Observatory of Sahara and Sahel (OSS) http://www.oss-online.org
- Climate Prediction and Applications Centre (IGAD) http://www.icpac.net
- Famine Early Warning Systems Network (FEWS) http://www.fews.net
- Southern Africa Regional Climate Outlook Forum SADC http://www.sadc.int

Latin America

- Drought Research Initiative (DRI) http://www.drinetwork.ca/
- International Research Centre on El Niño (CIIFEN) http://www.ciifen-int.org
- National Drought Mitigation Centre (NDMC) http://drought.unl.edu and Drought portal http://www.drought.gov
- Regional Committee on Hydraulic Resources (CRRH) http://www.recursoshidricos.org/
- Water Centre for Arid and Semi-Arid Zones in Latin America and the Caribbean (CAZALAC) http://www.cazalac.org
- Water Centre for Latin America and the Caribbean (CAALCA) http://centrodelagua.org

Asia

- Arid Land Research Centre (ALRC) http://www.alrc.tottori-u.ac.jp
- Drought Monitoring and Early Warning Centre Middle East http://jrcc.sa/
- National Climate Centre (China) http://cmdp.ncc.cma.gov.cn/extreme/dust.php?product=dust_moni
- Pacific Disaster Centre (PDC) http://www.pdc.org/

Global

- Integrated Drought Management Programme (IDMP) http://www.droughtmanagement.info
    - Regional IDMP for Central and Eastern Europe (IDMP CEE)
    - Regional IDMP in West Africa (IDMP WAF)
    - Integrated Drought Management Programme (IDMP) in the Horn of Africa
    - South Asian Drought Monitoring System (SA DMS)
    - Integrated Drought Management Initiatives in Central America
- International Water Management Institute (IWMI) http://www.iwmi.cgiar.org

2.3. The Water Balance Approach

The **crop water balance** approach keeps track of the soil water deficit by accounting for all water additions and subtractions from the soil root zone (Lhomme and Katerji, 1991). The major water additions are rainfall and irrigation, and the major subtractions are crop transpiration and soil evaporation (referred to together as evapotranspiration). The soil water content accounts of water balance during the crop cycle. The quantity of soil water in the root zone depends on soil depth and the storing water capacity. The soil has an upper and a lower limit of water content. The soil water availability for crop is the subtractions of the lower limit to the upper limit. The upper limit is called field capacity (FC), which is the amount of water that can be held by the soil against gravity after being saturated and drained. The lower limit is called permanent wilting point (PWP), which is the amount of water remaining in the soil when the plant permanently wilts.

The stored soil water is gradually depleted as the crop grows and extracts water from the soil to satisfy its evapotranspiration demand.

Agricultural drought is produced when crop evapotranspiration demand is higher than water availability (precipitation, irrigation and soil water availability).

Table 2 *General values of available water capacity (AWC).*

Soil texture	Low (%)	High (%)	Average (%)	AWC for one meter of soil depth (L/m^2)
Coarse sands	0.05	0.07	0.06	60
Fine sands	0.07	0.08	0.08	80
Loamy sands	0.07	0.10	0.08	80
Sandy loams	0.10	0.13	0.12	120
Fine sandy loams	0.13	0.17	0.15	150
Sandy clay loams	0.13	0.18	0.16	160
Loams	0.18	0.21	0.20	200

Silt loams	0.17	0.21	0.19	190
Silty clay loams	0.13	0.17	0.15	150
Clay loams	0.13	0.17	0.15	150
Silty clay	0.13	0.14	0.13	130
Clay	0.11	0.13	0.12	120

A simple model of crop water balance is:

Rainfall + Irrigation = Crop evapotranspiration + Runoff + Drainage ± Soil water content

For this exercise we will calculate:

Cumulated rainfall over the season (CR): it is the total rainfall during the growing season of crop, from sowing to harvest.

$$CR_{year} = \sum_{i=sowing\ day}^{n=harvest\ day} P_i$$

Where: CR is Cumulated rainfall over the season and P is the daily rainfall.

3. Class activity

The class activity has to be designed for a two-hour class session. Data from Central-America (Guatemala) will be provided to students. Dry season in Central America's 'Dry Corridor' goes from November to April, six months (Bot and Benites, 2005). Farmers choose either short cycle corn varieties (90 days) or medium cycle varieties (120 days). There are three sowing season:

- *Primera* season (May-August): is likely to begin after the dry season, from high-intensity rainfall to late July when a relatively dry period called “*canicula*” starts.
- *Postrera* season (September-December): occurs after *canicula and* begins in many areas with average rainfall to heavy rainfall due to the hurricane season (June-November)
- *Apante* season (January-April): usually is the dry season and commonly requires irrigation

For each season and year, students should calculate the accumulated rainfall, the accumulated evapotranspiration, and the index of crop water shortage.
Students should also be able to identify storm rainfall events in some years, which correspond with hurricane impacts.

3.1. Solution and evaluation criteria

The numerical solution must be provided by the teacher depending on the weather data used. Also, students' comments and class' discussions about the farmer risk will be evaluated. Table 3 and Table 4 show main statistics for the three crop seasons. *Primera* season (May-August) is the wet season with an average 776 mm of rainfall and low coefficient of variation, this is a sufficient amount to cover the water reference evapotranspiration (ETo) demand (579 mm) and actual crop evapotranspiration (ETc) of 450 mm. Looking deep in the data, dry days during this *primera* season take place at the beginning or at the end of the season. The *Postrera* season (September-December) showed lower rainfall, which is not enough to cover evapotranspiration. Thus, crop evapotranspiration is reduced as a consequence of water scarcity, which negatively affects crop yields. Finally, *Apante* season is not recommended for production of rainfed crops, as this is the driest season. Crop evapotranspiration in this season is higher than rainfall and we consider that the available soil water could provide roughly 122 mm for evapotranspiration. Coefficient of variation and quartile are a measure of variability and dispersion of the parameters.

Table 3 *Main statistics for crop season weather parameters from the weather station of Camotan Guatemala (1992 to 2012).*

Parameter	Primera season (May-August)	Postrera season (September-December)	Apante season (January-April)
Rainfall (mm)			
Average	776	395	52
Maximum	1,216	594	159
Minimum	412	191	4
Standard deviation	197	102	

			39
Coefficient of variation (CV)	25	26	74
First quartile (25% Percentile)	589	315	23
Third quartile (75% Percentile)	868	464	73
Reference Evapotranspiration (mm)			
Average	579	594	651
Maximum	654	733	712
Minimum	507	522	574
Standard deviation	47	57	37
Coefficient of variation (CV)	8	10	6
First quartile (25% Percentile)	541	538	628
Third quartile (75% Percentile)	620	626	677
Crop evapotranspiration (mm)			
Average	450	369	174
Maximum	535	445	248
Minimum	325	286	84
Standard deviation	55	48	42
Coefficient of variation (CV)	12	13	24
First quartile (25% Percentile)	425	324	146
Third quartile (75% Percentile)	501	407	208
Rain/ETo			
Average	135	67	8
Maximum	211	97	24
Minimum	73	26	1
Standard deviation	38	18	6

Coefficient of variation (CV)	28	27	73
First quartile (25% Percentile)	104	53	3
Third quartile (75% Percentile)	159	82	11

Table 4 shows a count of days during the seasons. The number of dry days increases from *Primera* to *Apante* season, and the coefficient of variation reduces. This shows the stability of the dry season from January to April. Wet days show the inverse behaviour of dry days, the wet season is stable in terms of wet days, with a minimum of 46 days per season. Days with rainfall over 40 mm are considered torrential. In this area the torrentiality is related with hurricanes and tropical storms (from August to October), with an average of six events per year. We correlated those heavy rains with hurricanes and tropical storm events and found a high relationship. For example: 31/10/1998 had 67.9 mm, which is related to hurricane Mitch (October 22 – November 5); 21/9/2001 had 66.3 mm, which is related to hurricane Jeanne (September 13 – 28); 31/5/2007 had 49.6 mm, which is related to Tropical Storm Barbara (2007); 4/7/2008 had 121.3 mm, which is related with Hurricane BERTHA; 20/7/2008 had 44.4 mm and 31/7/2008 had 43.7 mm, which are related with Hurricane Dolly (2008); 2/9/2010 had 49.1 mm, which is related to Tropical Storm Hermine (2010), 28/9/2011 had 64.4 mm, which is related to Hurricane OPHELIA (September 20 – October 3), 21/8/2012 had 46 mm and 22/8/2012 had 57.4 mm, which are related to Hurricane ISAAC[6].

Table 4 *Main statistics for dry and wet days during the crop seasons from the weather station of Camotan Guatemala (1992 to 2012).*

Type of days	Primera season (May-August)	Postrera season (September-December)	Apante season (January-April):
Days of crop season	123	122	121/120
Dry days			
Average	59	75	107
Maximum	77	87	118
Minimum	45	65	97
Standard deviation	9	6	6

[6] Data from National Hurricane Center: http://www.nhc.noaa.gov

Coefficient of variation (CV)	15	8	5
First quartile (25% Percentile)	50	70	102
Third quartile (75% Percentile)	64	78	111
Wet days			
Average	64	47	13
Maximum	78	57	23
Minimum	46	35	3
Standard deviation	9	6	6
Coefficient of variation (CV)	14	13	43
First quartile (25% Percentile)	59	44	9
Third quartile (75% Percentile)	74	52	19
Days over 40 mm			
Average	4	2	0
Maximum	8	5	1
Minimum	2	0	35
Standard deviation	2	1	6
Coefficient of variation (CV)	43	76	13
First quartile (25% Percentile)	3	1	44
Third quartile (75% Percentile)	5	3	52

After the activity, each student or group will present his or her findings. Speakers may use 10 minutes for presentation and 5 minutes for questions. Final evaluation will be the average of the class activity evaluation and oral presentation evaluation.

CLASS ACTIVITY EVALUATION CRITERIA:

Evaluation	**Criteria**	**Score**
Overall Impression		
Excellent	The student initiates and maintains interaction with other students and instructor from the beginning of the class, shows leadership in group activities, attempts to compare and contrast course material across subject areas, is willing to help other students understand material, always prepared for class	20
Good	The student shows willingness to participate, cooperates fully in discussions and group activities although may not necessarily be the leader, answers readily when called upon, elaborates somewhat on answers	15
Fair	The student participates more passively than actively, is off topic or distracting, especially in small group activities, does not elaborate on answers or statements, is frequently not well prepared.	10
Weak	The student is unable to answer when called upon in class; obviously unprepared, is disruptive, prevents other students from hearing, etc., rarely participates in class activities, is disrespectful of other students and instructors, has negative attitude – refuses to answer questions and constantly introduces unwarranted criticism of other students and guest instructors.	5

ORAL PRESENTATION EVALUATION CRITERIA:

Evaluation	**Criteria**	**Score**
Delivery, Overall Impression and Use of Communication Aid		
Excellent	Enthusiastic, poised, comprehensible, can be heard by all, interesting to audience. Includes clear statements of each of the following: Topic background, question, hypothesis, variables, methods used, results, and conclusions.	20
Good	Moderately enthusiastic, comprehensible, generally can be heard, and moderately interesting.	15
Fair	Only mild enthusiasm, problems with comprehensibility, cannot be heard very well, not very interesting to audience.	10

Weak	No interest in presentation, barely or incomprehensible.	5

Fluency and organization		
Excellent	Gets the idea across fully with little hesitation; goes beyond the minimum. Communicates with ease overall.	20
Good	Communicates confidently using simple structures; some hesitation and false starts with more complex material. Evidence of fluency outweighs moments of uncertainty or stumbling.	15
Fair	Consistently uses simple structures, vocabulary, and avoids more complex material. Some signs of fluency, but hesitant performance and/or excessively simple language predominates.	10
Weak	Use of simple structures is uncertain and hesitant. Little evidence of fluency despite moments of ease.	5

Familiarity with subject		
Excellent	Speaker demonstrates adequate knowledge of the subject. He/she answers questions fully and clearly. Informative; original and well-developed ideas; demonstrates creativity; and/or detailed coverage of topic.	20
Good	Topic covered; limited development of ideas; most information relevant to topic, at least some social conventions included; creative.	15
Fair	Lacks logical sequencing; little substance; says less than required.	10
Weak	Little information conveyed, disconnected or disorganized ideas.	5

Results		
Excellent	Speaker provides an accurate and complete explanation of key concepts, drawing upon relevant references. Applications of concepts are included to illuminate issues. Listeners gain insights.	20
Good	For the most part, explanations of concepts and Theories are accurate and complete. Some helpful applications are included.	15

Fair	Explanations of concepts are inaccurate or incomplete. Little attempt is made to tie theory to practice. Listeners gain little from the presentation.	10
Weak	Presentation is very confused and unclear. Listeners gain no new insights.	5

Length of Presentation		
Excellent	Presentation is within time limit. Length of each point is according with its importance.	20
Good	Presentation is within time limit. But the time distribution is irregular.	15
Fair	Speaker is too fast or too slow, repetitive or skipping important details.	10
Weak	Presentation is far too long or far too short.	5

4. Homework activity

An 8-12 hour activity for class and homework has to be designed, to be carried out preferably in groups. The exact methodology for the activity has to be selected by the lecturer to best fit the needs of the discipline covered.

Historical daily rainfall data could be collected from Bureau of Meteorology, a minimum set of 20 to 30 years if it is available as a shorter data set reduces the accuracy of the results. A spreadsheet based daily water balance model could be developed considering daily rainfall, soil water content and crop reference evapotranspiration. Also flood damage could be evaluated. This activity should follow on from the exercise that the students did in classroom activity.

4.1. Solution and evaluation criteria

Solution of homework activity depends on the data source used by students. The solution must follow the same criteria presented for the class activity, but adapted to the new material. The evaluation criteria for the homework report consist of the following:

HOMEWORK REPORT EVALUATION CRITERIA:

Evaluation	**Criteria**	**Score**
Delivery, Overall Impression and Written Communication Skills		
Excellent	The report is organized following the standard research reporting protocol (abstract, motivation, methods, results, analysis, discussion and conclusions). Includes clear statements of each of the following: Topic background, question, hypothesis, variables, methods used, results, and conclusion. The report is written with an objective tone. The full range of interpretations of results is presented. The reports and research findings of others are referred to neutrally without attacking the authors' opinions. Results are carefully and objectively analyzed and interpreted.	20
Good	The activity's objectives are presented. The motivation for pursuing the report and its relevance are addressed. The discussion is reasonably clear. The key elements of the standard research reporting protocol are present, but they may be structured in a nonstandard manner. Within sections, the order in which ideas are presented may be occasionally confusing. The report is primarily objective and neutral in tone, and a variety of interpretations of results is presented. Any subjectivity is minor, and any failure to acknowledge the work of others seems to be an oversight. Engineering analysis is detailed enough to aid understanding.	15
Fair	Engineering analysis is so sketchy and inadequate that the reader is not able to evaluate the validity of the interpretation of findings.	10
Weak	The presentation is poor or incomprehensible.	5

Evaluation	**Criteria**	**Score**
Technical solutions and content		
Excellent	An accurate and complete explanation of key concepts and theories is made, drawing on relevant literature. Enough detail is presented to allow the reader to understand the content and make	20

	judgments about it. In addition, applications of theory are included to illuminate issues. Readers gain insights. Information (names, facts, etc.) included in the report is consistently accurate.	
Good	An accurate and complete explanation of key concepts and theories is made, drawing on relevant literature. Enough detail is presented to allow the reader to understand the content and make judgments about it. With some minor exceptions, the information (names, facts, etc.) included in the report is accurate.	15
Fair	The explanation is sufficiently inaccurate, incomplete, or confusing that the reader gains little information from the report. It appears that little attempt has been made to help the reader understand the material.	10
Weak	The information in the report is incorrect or unclear to the point of being misleading.	5

Evaluation	**Criteria**	**Score**
Professional Style		
Excellent	Engineering terms and jargon are used correctly. They are defined the first time they are used in the report. Sentences are complete and grammatical, and they flow together easily. All figures, graphs, charts, and drawings are accurate, consistent with the text, and of good quality. They enhance understanding of the text. All are labeled correctly in accordance with engineering standards and are referred to in the text. The document is visually appealing. White space and color are used appropriately to separate blocks of text and add emphasis. The reader can easily navigate the document.	20
Good	For the most part, terms and jargon are used correctly with some attempt to define them. For the most part, sentences are complete and grammatical, and they flow together easily. Any errors are minor and do not distract the reader. Repetition of the same words and phrases is avoided. For the most part, figures, graphs, charts, and drawings are accurate, consistent with the text, and of good quality. They are	15

	generally labeled correctly in accordance with engineering standards. All are referred to in the text.	
Fair	There is an overuse of jargon and technical terms without adequate explanation of their meaning. Errors in sentence structure and grammar are frequent enough that they distract the reader and interfere with meaning. There is unnecessary repetition of the same words and phrases. Figures, graphs, charts, and drawings are of poor quality, have numerous inaccuracies and mislabeling, or may be missing. There may be no corresponding explanatory text or there may be redundancy with the text.	10
Weak	The document is not visually appealing and there are few “cues” to help the reader navigate the document. Little attempt is made to acknowledge the work of others.	5

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FURTHER/SUGGESTED MATERIAL

- **Book**: Dixon, J., Gulliver A., Gibbon D. 2001. Farming Systems and Poverty: Improving Farmers' Livelihoods in a Changing World. FAO and World Bank.
    - Summary: http://www.fao.org/3/a-ac349e.pdf
    - English: ftp://ftp.fao.org/docrep/fao/003/y1860e/y1860e.pdf
    - Spanish: ftp://ftp.fao.org/docrep/fao/003/y1860s/y1860s00.pdf

- **Video:** What Causes Drought? https://www.youtube.com/watch?v=IOIV7Aulty4
- **Video:** Floods and Droughts : Two Problems with One Solution https://www.youtube.com/watch?v=vj3UwWETaNo
- **Video:** Coping with drought (Kenya), https://www.youtube.com/watch?v=8TSHA6-UqGI
- **Report:** Agricultural drought assessment report (India), http://jsac.jharkhand.gov.in/pdf/Drought/Drough_assessment_october2012-Part1_1.pdf
- **Report:** World Meteorological Organization: Drought within the context of the region VI (Europe), http://www.wmo.int/pages/prog/hwrp/documents/regions/DOC8.pdf
- **Article:** Hess, U., Richter, K., Stoppa, A. Weather Risk Management for Agriculture and Agri-Business in Developing Countries. FAO. http://www.fao.org/uploads/media/Weather%20Risk%20Management%20for%20Agriculture%20and%20Agri-Business%20in%20Developing%20Countries.pdf
- **Article:** Rojas, O., Vrieling, A., Rembold F. Assessing drought probability for agricultural areas in Africa with coarse resolution remote sensing imagery, http://www.fao.org/climatechange/38004-05a54c6f3e665ea2fabdec165b7948383.pdf
- **PPT presentation:** Irrigation & Water Requirements of Vegetable Crops, http://es.slideshare.net/munishsharma0255/irrigation-water-requirements-of-vegetable-crops
- **PPT presentation:** Coping with drought in crop improvement -- a global perspective, http://es.slideshare.net/GCProgramme/coping-withdrought-id4jmribaut2013
- **PPT presentation:** T12- Agriculture drought and land degradation loss in arab region, http://www.slideshare.net/NENAwaterscarcity/t12-wadid-erian-lw-18-12-2013-economics-ld-and-d-presentation
- **PPT presentation:** From Drought Management Strategies to Drought Management Policies, http://es.slideshare.net/gwpceewaterpartnership/joint-gwp-ceedmcsee-training-14-greece-from-drought-strategies-to-policieskaravitis

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