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FAO agroclimatic databases and mapping tools

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1. Background

The Agroecological Zone (AEZ) Project was started by FAO in the 1980s to assess the global agricultural production potential in developing countries. Essential data requirements, next to level of technology, included available environmental resources such as soils and climate.

At the time of the first AEZ publications, the FAO climate database included about 3200 stations. The number has been growing constantly to reach about 30,000 currently. The scope of the database has also changed, with the number of Member countries increasing (for instance, Uzbekistan, Kyrgyzstan...) and the emphasis moving more towards the support of the Multilateral Environmental Agreements (conventions on biodiversity, climate change and desertification). As a result, efforts had to be made to expand the database from developing countries coverage to global coverage, updating the averages to more recent reference periods, ideally 1971-2000 (but more often 1961-90). The averages are either obtained from national meteorological services, from other published databases, or recalculated by FAO based on time series. Particular efforts have been made recently to develop a more complete set of data for potential evapotranspiration according to Penman-Monteith (FAO-Penman-Monteith PET).

2. Data availability

The database is maintained by the FAO Environment and Natural Resources Service (SDRN) in the Sustainable Development Department. It is usually referred to as FAOCLIM[1]. It has been the policy of

FAO to make agroclimatic and agrometeorological data, as well as software tools easily available. They

can be downloaded from the internet link listed in the footnote[2].

FAOCLIM contains monthly data for up to 14 observed and computed agroclimatic parameters: minimum, maximum and average temperatures, computed daytime and nighttime temperatures, rainfall, PET (computed), moisture expressed as dewpoint, vapour pressure or relative humidity, wind speed, and solar energy as sunshine hours, sunshine fraction or radiation. Needless to say, average temperature and rainfall are the most commonly available parameters.

Regarding averages, the data availability is as given in the table below.

Variable	Number of Stations	EMD[3] in km
Mean Temperature	20828	48.36
Mean Minimum Temperature	11550	64.94
Mean Maximum Temperature	11544	64.96
Precipitation	27375	41.71
PET	4285	106.62
Wind speed	3779	113.5
Water Vapour Pressure	3959	110.92

As to time series, they include 30941 individual series of monthly data for 8 variables. 30% of the series refer to rainfall and 30% to temperatures. The average length of the series is just under 50 years. Some series exceed 200 years, while the longest rainfall series covers 299 years. On the other hand, 185 rainfall series include only one year.

80% of the series exceed 20 years and about 45 % is longer than 50 years. This corresponds to an effective maximum distance between stations of 62 Km for rainfall series of 20 years. 90% of rainfall time series and 86% of temperature series have no gaps, i.e. on average a missing data item occurs over 10 years for rainfall time series.
The availability of time series data varies widely according to continents.

[1] A detailed statistical analysis of the contents of the database, with special focus on time series, was prepared (in German) by J. Grieser. The document is available upon request from the author or from agromet@fao.org.

[2] ftp://ext-ftp.fao.org/SD/Upload/Agromet

[3] EMD is the effective maximum distance to the nearest station. It is half the distance between two stations if the stations were homogeneously distributed.

Inventory of time series of various variables according to continents

	Africa	Asia	America	Europe	Oceania	Antarctic	World
Rainfall	3395	2172	5611	1389	915	48	13530
T_Avg	605	1256	2765	765	515	90	5996
T_Min	223	653	1869	263	341		3349
T_Max	223	653	1690	263	341		3170
Rel. Hum.	454	256	366	341	57	2	1585
Vapor Pres.	433	477	599	446	61	2	2018
PET	90	63					153
Sunshine	352	231	388	278			1249
Sum	5775	5761	13288	3745	2230	142	30941

"standard" FAOCLIM dataset, but could be made available upon request. The data are managed using MS-Access and Oracle in FAO HQ.

Monthly data for up to 14 parameters, and time series for rainfall and temperatures are available as the "FAOCLIM CD-ROM" (currently in version 2), published in 2001 as Number 5 in the SDRN Working Papers Series. The CD-ROM includes two pieces of software to access the data: (1) FAOCLIM proper, to select data by geographic area, time period and parameter, and export them for processing by other software packages; (2) GeoContext, a user-friendly programme to visualise the information in graph form.

Since FAOCLIM Version 1 was published in 1994, considerable progress was made in easily available software tools to spatially interpolate climatic data[5]. FAO has published the LocClim CD-ROM in 2001 as Number 9 in the Environment and Natural Resources Service (SDRN) Working Papers series.

3.2. LocClim[6]

LocClim (short for Local Climate) was developed to provide an estimate of climatic conditions at locations for which no observations are available. To achieve this, the programme uses the stations of FAOCLIM 2.0

Next to a "no questions asked" automatic mode, the "workbench" mode gives the user full control over the interpolation procedure (Inverse Distance Weighting, IDW). Inputs can be taken from the keyboard (location specified either by co-ordinates or by a click on a map) or from user-provided ASCII files. Output can be in the form of ASCII files or user-defined georeferenced grids[7].

The programme also provides estimates of growing season characteristics based on a comparison of rainfall and potential evapotranspiration (Franquin's method). Estimates of monthly, 10-daily and daily values of common climate variables are given together with error estimates, using a number of options to correct for regional variability, altitude dependency and horizontal gradients of the variables. For any given location LocClim searches for the nearest stations that fulfil given criteria (absolute number, maximum distance, altitude constraints). If desired LocClim fits a linear altitude function through the observations to reduce all of them to the elevation of the desired location. This minimises the systematic error resulting from the different elevations of the neighbouring stations.

The altitude of the desired location can either be given by the user or taken from a built-in digital elevation model (DEM) with a spatial resolution of 10 km and an altitudinal resolution of 20 m (DEM downgraded from the NOAA/NCDC Global Land One-kilometre Base Elevation). LocClim can perform climate gradient correction by fitting a plane surface to the observations over the latitude-longitude plane. Thus the smooth geographical climate variation is taken into consideration. If desired a shadowing routine can be applied that reduces the influence of neighbours hidden by closer neighbours.

The results of spatial interpolation strongly depend on the station data used. Under some circumstances the reliability of the results is questionable. LocClim warns the user in these cases, e.g. if

- all the stations used for the interpolation are higher/lower than the target point (vertical extrapolation);
- the location is not among a group of neighbouring stations (horizontal extrapolation);
- the data of one of the stations does significantly differ from those of the other stations (strange data);
- less stations than expected fulfil the constraints chosen by the user (few data).

The workbench mode allows for a fine tuning of the interpolation by consideration of the warnings and error estimates.

3.3 Web_LocClim

Since LocClim Ver.1 was published in 2002, a simplified web version was developed[8]. The version is "simplified" in that it offers fewer options to fine-tune the interpolation than the full CD-ROM version.

[4] http://www.fao.org/sd/2001/EN1102_en.htm

[5] Bogaert P., Mahau P. and Beckers F., 1995. "The Spatial Interpolation of Agro-Climatic Data. Cokriging Software and Source Data. User's Manual". FAO Agrometeorology Working Papers N. 12, FAO, Rome, 70 pp. plus diskette.

[6] http://www.fao.org/sd/2002/EN1203a_en.htm

[7] The grids are in WinDisp format; see below for details about WinDisp

[8] http://www.fao.org/sd/locclim/srv/en/locclim.home

The Web_LocClim site allows other servers to perform interoperability transactions: other servers can directly query the LocClim service to get climate data that they can process for their own purposes. Technical information about the interoperability service can be obtained from the website listed in the footnote[9] of from agromet@fao.org.

3.4 New_LocCLim Ver.1

A new version of LocClim (New_LocClim) was developed in collaboration with the Deutscher Wetterdienst (German Weather Service), more specifically the Global Precipitation Climatology Centre GPCC[10]. The New_LocClim has all the standard interpolation methods (IDW, kriging, Shepard, thin-plate splines…) and a number of added functionalities in comparison to LocClim.
While the main aim of LocClim was the investigation of local climate conditions at any location on earth based on the FAOCLIM database, New_LocClim aims at the preparation and investigation of climate maps. One of the most useful additions is the possibility for users to interpolate their own data and to prepare maps (grids) at any spatial resolution. Aside maps of the interpolated variables New_LocClim offers maps of useful supplementary information like horizontal and vertical gradients, estimated errors, portion of variance explained by gradients, as well as warnings in case of sparse or strange data and extrapolations. All maps can be superposed with geographic information such as boundaries, rivers, roads, railway tracks and station information (altitude, co-ordinates, estimated local errors, gradients and strange-data warnings). A statistics sheet provides both grid and station statistics as well as altitude dependencies.
A single-point mode allows for the investigation of the mean annual cycle (monthly, dekadal, and daily resolution) of 8 climate variables at a time as well as the estimation of growing season characteristics like number of growing seasons per year, lengths, begin dates, averages and aggregates of climate variables during growing season.
The underlying FAOCLIM database was also significantly improved, in particular as regards data coverage in developed countries and countries in transition, PET availability, and the inclusion of daytime and night-time temperatures. The New_LocCLim Ver.1 in fact constitutes the convergence of FAOCLIM Ver.2 with LocClim Ver.1 and the publication of FAOCLIM will be discontinued. The joint publication of the New_LocClim by FAO/SDRN and the GPCC is planned for late 2004.

3.5 WinDisp Ver.5[11]

WinDisp is a public domain, easy to use software package developed by FAO and a number of other partners (USAID, US Forest Service, US Geological Survey, Famine Early Warning System, European Union) for the display and analysis of satellite images, maps and associated databases, with an emphasis on early warning for food security. WinDisp was originally called IDA (Image Display and Analysis) and it was developed for the FAO Global Information and Early Warning System (GIEWS[12]). Therefore the WinDisp image format is often referred to as the "IDA format".
WinDisp allows users to:
• Display and analyse satellite images
• Compare two images and analyse trends in a time-series of images
• Extract and graph trends from a number of satellite images such as during the growing season for comparison with other years
• Compute new images from a series of images
• Display tabular data in map format
• Build custom products combining images, maps and specialised legends
• Write and execute batch files to automate routine and tedious tasks
• Build a customized project interface for providing users with detailed menus of available data for a country or a specific area.

3.6 AgroMet Shell (AMS) and SEDI (Satellite Enhanced Data Interpolation)

AgroMetShell (AMS) provides a toolbox for agrometeorological crop monitoring and forecasting. The programme includes a database that holds all the weather, climate and crop data needed to analyse weather impact on crops.
The FAO Crop Specific Soil Water Balance produces a number of outputs: water balance variables, such as soil moisture, actual evapotranspiration over the vegetative phase or the water stress at flowering, etc. They can be mapped separately for crop monitoring.
The mapping tools of relevance to this description of FAO agroclimatic databases refer to the SEDI methodology. SEDI (Satellite Enhanced Data Interpolation) is a function first included in WINDISP, but subsequently improved and incorporated in the AMS as a standard tool to map the results of the agrometeorological analyses and impact assessments.
SEDI takes advantage of the correlation between the point data to be mapped (for instance monthly temperature) and an "environmental variable", that is available as a grid, for instance a digital terrain model. Other examples include point rainfall with a satellite-based cloud index, or crop yield with Normalized Difference Vegetation Indices (NDVI; the index is now available at various resolutions from several earth observation satellites)

[9] http://www.fao.org/sd/locclim/html/en/interoperability.html
[10] http://gpcc.dwd.de
[11] http://www.fao.org/giews/english/windsp.htm
[12] http://www.fao.org/giews/english/index.htm

The methods proved powerful and versatile, and it is now regularly used by FAO to spatially interpolate climate and agronomic parameters[13].

SEDI is a simple and straightforward method for 'assisted' interpolation. The method can be applied to any parameter of which the values are available for a number of geographical locations, as long as a 'background' field is available that has a negative or positive relation to the parameter that needs to be interpolated.

4. Looking ahead

Availability of new data and new methods, evolving software fashions and tools and a user base in developing countries (but not only) are some of the factors that have been driving the agroclimatic activities in FAO over the last thirty years.

Clearly, the development of software and methods is an ongoing process. The current priorities include essentially two trends: the better integration of the tools through a greater adherence to standards (such as the adoption of GeoTIFF next to the "native" IDA/WinDisp format), and the focus on agronomic value-adding to the climate data proper.

[13] Gommes R. and P. Hoefsloot, 1998. Gaps in maps, estimation of missing data in agricultural statistics maps. Pp 155-168 in: Proc. Of the EU/COST-79 Seminar on Data Spatial Distribution in Meteorology and Climatology, Volterra, 28 Sep.-3 Oct. 1997, EU, Luxembourg, EUR18472, 226 pp.