GLOBAL DATABASE FOR GEOSPATIAL INDICATORS

Jeffrey B. Miller, David Cunningham, Gregory Koeln
Earth Satellite Corporation
Rockville, Maryland
info@earthsat.com

Douglas Way, Joshua Metzler, Richard Cicone
ISciences, LLC
Ann Arbor, Michigan
info@isciences.com

ABSTRACT

Geospatial Indicators (GI) is an exploration into the use of GIS, remote sensing and spatial reasoning methods to identify regions at risk due to inadequate food and water resources that are a result of inherent environmental scarcity, stress due to environmental dynamics and change, or inadequate social capital. To support the GI modeling effort, a database of natural and social features scalable to one to one million and including over thirty spatial data themes is constructed from extant open data sources. Recent scientific efforts have stimulated the creation of numerous well-resolved global databases representing environmental and social parameters of importance to science, such as, global vegetation, disaggregated population, topography, land surface features such as road and rail, hydrography and land cover—these state-of-the practice databases are now in a unified Global Database (GDB). Most original sources lacked structural uniformity—representing earth features at different scales, projections, and formats. A need therefore existed to prepare a harmonized database. GDB has been constructed for all developing nations. Additionally "geospatial indicator" models required estimates of certain parameters that needed to be derived from extant data. Derived features include population projections to 2010, hazard risk maps for severe storms, flooding, tsunami, earthquake and volcano, agricultural primeness, infrastructure intensity and disaggregated GDP.

INTRODUCTION

Technology, science and defense interests have recently stimulated the creation of numerous well-resolved global databases representing environmental and social parameters of importance in identifying geospatial indicators of environmental and social security. Scientific interest in how earth works as a geobiophysical system has spawned numerous research programs such as the International Geosphere and Biosphere Programme (IGBP) and the Human Dimensions of Global Environmental Change Programme. Such research interest has given impetus to the development of global scale data sets to represent environmental and social factors of concern to science, such as the Global Land Cover Characteristics (GLCC) database (Loveland, 2000) and the GLOBE digital elevation model, (Hasting, 1998). The US Global Change Research Program in particular has fostered cooperation between NASA, NOAA, and other US and foreign agencies toward the development of time-history data sets based on remote sensing sources like the Advanced Very High Resolution (AVHRR) Land Pathfinder Database – a twenty year record of Earth surface radiation from which one can discern surface albedo characteristics and estimate vegetation dynamics and land cover changes (GSFC, 2002). Defense interests have recently provided open source digital versions of military paper maps such as the Digital Chart of the World (Danko, 1992 and DMA, 1992)), and representations of population distribution such as the Oak Ridge National Labs (ORNL) LandScan Database – providing estimates of population density for every one square kilometer area on earth (Dobson, 1999).

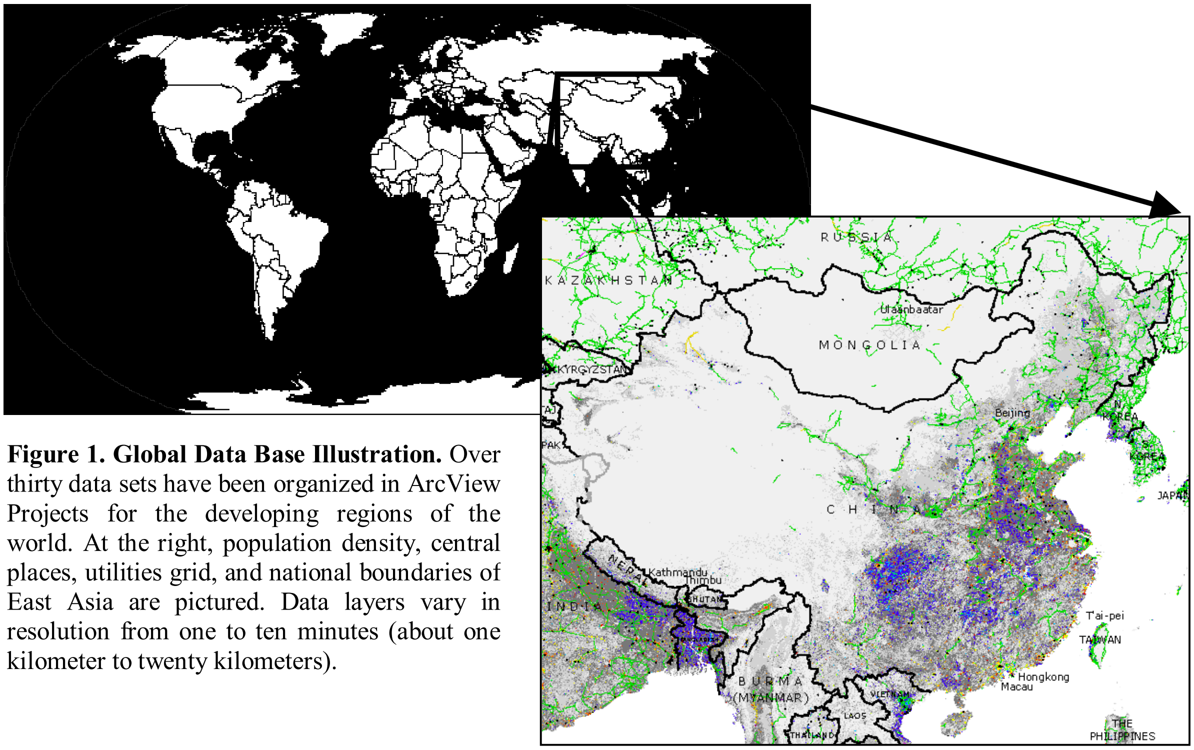


Figure 1. Global Data Base Illustration. Over thirty data sets have been organized in ArcView Projects for the developing regions of the world. At the right, population density, central places, utilities grid, and national boundaries of East Asia are pictured. Data layers vary in resolution from one to ten minutes (about one kilometer to twenty kilometers).

Without the efforts of scientific data pioneers, original preparation of such a collection of global data sets for purposes of estimating indicators of environmental and societal security would have been an insurmountable task. However, most of the available sources lacked structural uniformity – representing earth features at different scales, projections, and formats. A need therefore existed to prepare a harmonized Global Data Base (GDB). Such a database was constructed for all developing nations including the continents of Africa, Asia, and South America, and developing nations and transitional economies of North America and Europe. Additionally, envisioned water and food balance models of the Geospatial Indicators effort required estimates of certain parameters, such as food production capacity, that needed to be derived from other data. Figure 1 illustrates the terrestrial extent of the developed database.

DATA BASE DESIGN

The Global Database (GDB) provides the core data from which vulnerability, stress, and capacity models of Geospatial Indicators are derived (see Cicone, 2002; and Parris, 2002).. Generally data are estimated at scales of approximately one kilometer square, analogous to map accuracies of about one to one million. Over thirty data sets are ingested into an Environmental Systems Research Institute (ESRI) ArcView environment available on CDROM for eleven regions of the world. Each region is presented in a geographic projection optimal for the region of interest. All but developed nations of the world are represented. The data are arranged as themes on ArcView projects (".apr" files). This convenient presentation allows users to select layers to view, query and overlay. Both raster and vector data are available. The spatial data extension of ArcView allows users to modify color schemes and quantization levels of raster data layers. In many cases additional data layers are available on disk that can be imported to the ArcView project by the user. Data layers are presented in Table 1 and illustrated on Figure 2. The recently developed USGS Global GIS Database provides a complementary set of data (USGS, 2002). Though these databases have not been harmonized into a common projection, researchers adept at the use of ESRI software products are able to create a wide variety of map presentations to support analysis or report preparation.

Core Data Features, Derived Features, Dynamic Features

GDB is composed of several types of data originally ranging in scale format. *Core* GDB data layers were drawn from extant GIS and statistical sources documented in Table 1. GIS sources included raster-based data sets (e.g., GTOPO30 digital elevation) and vector based data sets (e.g., watershed boundaries). Statistical resources (e.g. FAO Stats) were generally expressed in tables, with explicit geographic referencing using a country or region name. Most of these sources are temporally static representations of natural and human terrestrial features (for example, population density at a point in time). Such static data are used by Geospatial Indicator (GI) models to estimate the inherent risk of food and water insecurity in a given area. GI models depend on time-series or *dynamic* data like monthly precipitation measurements to estimate the likelihood of insecurity. GI represents risk and likelihood as the possible imbalance between available and required food resources. Hence, models estimate food production capacity, distribution, and demand, none of which is available in extant resources. *Derived features* were therefore generated from core data using Geospatial analytic techniques to simulate various needed terrestrial factors. Several derived features are described in greater detail in the next section. *Risk surfaces* are then estimated to determine the structural balance of food and water supply and demand. Estimation methods employed to model risk surfaces are described below.

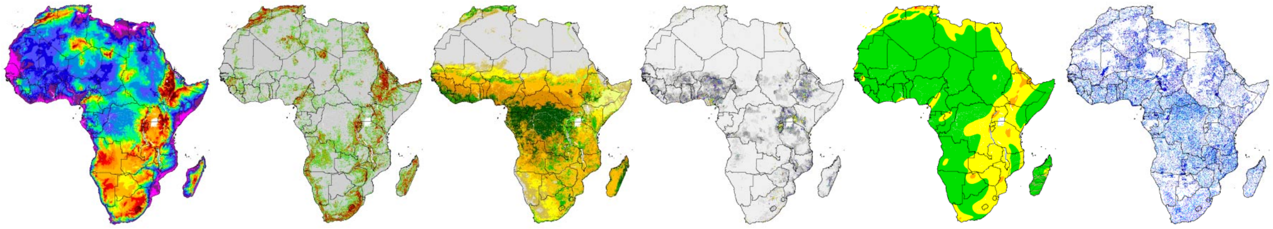


Figure 2. Global Data Base. From left to right, elevation, slope, land cover, population, earthquake risk, and flood risk illustrate a number of factors modeled at scales of approximately 1:1 million.

Table 1. Global Data Base Data Layers. Data are structured as core GIS spatial data layers the foundation pieces for estimating vulnerability, time series data used to estimate stress, statistical data used to estimate capacity, and derived features computed from the above.

Core GIS Data Layers

- Population density. LandScan, 1998 Global Population. Oak Ridge National Laboratory. 30 arc second grid, geographic projection.
- Land cover. IGBP Global Land Characterization. EROS Data Center, one kilometer grid, Goodes Homosoline.
- Topography (Earth Elevation). GTOPO30. EROS Data Center. 30 arc second grid, geographic projection.
- Irrigated agriculture. University of Kassel, Kassel Germany. Thirty degree grid, geographic projection.
- Soil suitability for agricultural use. UN Food and Agriculture Organization Soils, 1974-1978 source map, digitized 1995.
- Watershed boundaries. EROS Data Center.
- Drainage (water bodies and rivers). Digital Chart of the World. Defense Mapping Agency.
- Central places. Digital Chart of the World.
- Administrative Geography. Digital Chart of the World.
- Transportation (roads, rail, aeronautical points). Digital Chart of the World.
- Electrical utilities grid. Digital Chart of the World.
- City and industrial infrastructure. Persistent night-time lights. NOAA National Geophysical Data Center.
- Groundwater recharge coefficients, ESRI ArcAtlas, Our Earth, November 1998.
- Runoff coefficients, ESRI ArcAtlas, Our Earth, November 1998.
- Average annual evapotranspiration.
- Annual average rainfall, temperature and cloud cover. 1931-1960. Leemans, R., and Cramer, W.P. 1992. IIASA Database for Mean Monthly Values of Temperature, Precipitation, and Cloudiness on a Global Terrestrial Grid.

Digital Raster Data on a 30 minute Cartesian Orthonormal Geodetic (lat/long) 360x720 grid. In: Global Ecosystems Database Version 2.0. Boulder, CO: NOAA National Geophysical Data Center.

- Persistent night time lights, NOAA DMSP Program, National Geophysical Data Center
- Historical Storm Tracks, NOAA historical storm tracks database, 1971-1995.
- Tsunami history. National Geophysical Data Center Natural Hazards World Wide Event Database.
- Earthquake history. National Geophysical Data Center Natural Hazards World Wide Event Database.
- Peak ground acceleration. Global Seismic Hazard Assessment Program.

Dynamic Features: Time-series data

- Vegetation Greenness. AVHRR Land Pathfinder database. NASA Goddard Space Flight Center. 8 km resolution grid, Goode's homolosine. (GSFC, 2002)
- Precipitation. Global Precipitation Climatology Center, one degree grid, geographic projection. (GPCC, 2002)

Statistical Data Bases

- Governance, Aggregate Government Indicators, World Bank.
- Income distribution, World Income Inequality Database (WIID), UN University World Institute for Development Division for Economic Research. (Kaufmann, 1999)
- Socioeconomic, World Development Indicators, World Bank.
- Agricultural, FAO Stats, UN Food and Agriculture Organization.
- National Water Consumption Estimates, 1998, World Resource Institute

Derived features

- Primeness of Agricultural Lands (see below, Composition of Derived Features)
- Disaggregated wealth, purchasing power parity gross domestic product per km sq. (see below, Composition of Derived Features)
- Infrastructure intensity, from transportation, utility and night lights. (see below, Composition of Derived Features)
- Projected population density (2025) (see below, Composition of Derived Features)
- Terrain slope, from elevation.
- Earthquake Hazard Areas, likely earthquake damage in the next 50 years from historical earthquakes and peak ground acceleration.
- Volcano hazard areas from volcano history based on Mercali scale.
- Topographic flood risk areas from drainage, elevation and slope.
- Cyclonic storm risk areas from storm track history.
- Tsunami hazard areas, from Tsunami history.
- Average Governance Index, from Aggregate Government Indicators.
- GINI Index (estimate), from WIID.
- Food import distribution, production, demand and balance.
  Water supply, demand, and balance From Geospatial Indicators model.

COMPOSITION OF DERIVED FEATURES

Geospatial analytic methods were used to derive information from core data needed to support GI models. Several of these derived features are described in the following, specifically: 1. agricultural primeness, an estimate of the caloric production potential for each kilometer of potential cultivated land; 2. disaggregated gross domestic product (GDP), an allocation of nationally reported GDP to each one kilometer parcel, based on spatial economic correlates; and 3. infrastructure intensity, an estimate of development intensity as a function of transportation and industrial infrastructure.

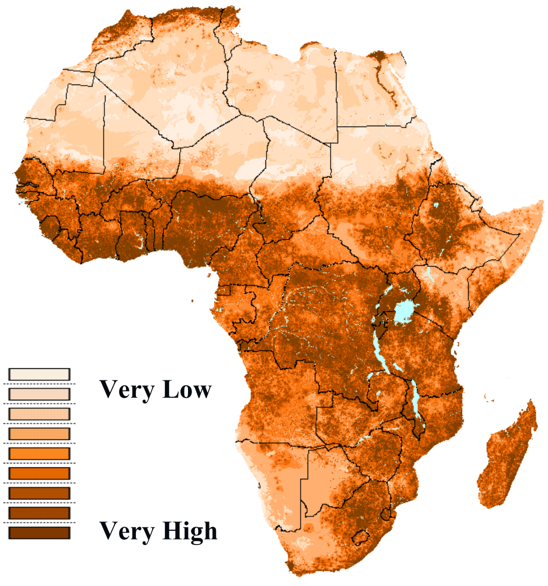
The creation of derived geographic data layers attempt to follow model-based scientific guidelines, but due to data limitations are very often subject to heuristics and creative utilization of data layers. The role that persistent night lights played will serve to illustrate this point.

Persistent night-time lights extracted from the DMSP Operational Linescan System by the NOAA National Geophysical Data Center (Elvidge, 1997) proves to be an important surrogate for anthropogenic features that are not otherwise available globally. Persistent night lights provide a depiction of the frequency that anthropogenic illumination (city lights, transportation corridors, industrial areas) occurs over the period of about one year. Taking advantage of the correspondence of night lights to built-up areas, night lights were employed to map industrial intensity, a measure of economic prowess and activity used in agricultural primeness to identify potential agricultural markets, in disaggregated GDP, to identify strength of economic activity, and infrastructure intensity to augment identification of settlement patterns.

Agricultural Primeness

Food production statistics are reported by the United Nations Food and Agriculture Organization (FAO) as national level numbers. Since much of the developing world depends on subsistence agriculture and local food supplies, estimates of local food availability are required. To estimate this, GI first creates an approximation of land carrying capacity based on environmental and social factors. A measure of agriculture primeness is created by a cartographic model that considers the inherent physical conditions necessary to support agriculture - climate, land, and proximity to transport infrastructure and markets. Thus, this model maps the differential ability of a country's agricultural land to produce food.

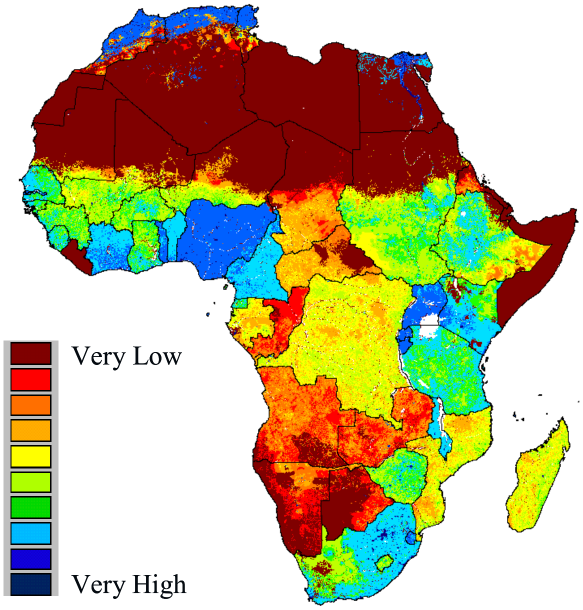
The primeness measure provides an indicator of production potential that can be used in conjunction with information about location of arable land and reported crop production statistics to produce a disaggregated estimate of food production. Agricultural "primeness" is estimated by considering three factors: the availability of moisture, the suitability of the terrain, and accessibility to markets. The first two factors establish the inherent quality of the land, while accessibility to markets is a measure of the potential willingness of a farmer to develop that land through development of irrigation, application of fertilizer, or other agronomic factors influencing the land's yield potential. The GI model presumes accessibility to markets as a surrogate measure of such intent.



Factors used to estimate availability of moisture include average annual precipitation, access to surface water supply, and land cover. Access to surface water is determined by a proximity analysis where close proximity from rivers and streams adds value and conversely, areas far from water receive low value. Terrain suitability is a function of soil type and steepness of slope. Soils, available from FAO, are ranked by an "expert" agronomist as to their suitability to support sustainable cultivation. Terrain slope favors flat and low sloping land and conversely, penalizes very steep slopes. It should be noted that the combined effect of proximity to water and low slope also correlates as to where irrigated land, if it occurs, is found. Total precipitation adds additional weight in the model as a function of total water availability. Thus, the highest value agricultural land receives moderate to high annual precipitation, is located on flat slopes, contains fertile soils, and is in close proximity to surface water. Access to markets is estimated using information about location of settlements and central places, and transportation infrastructure. Settlement location is derived from location records in Digital Chart of the World together with indications from the persistent light data set.

Disaggregated Gross Domestic Product

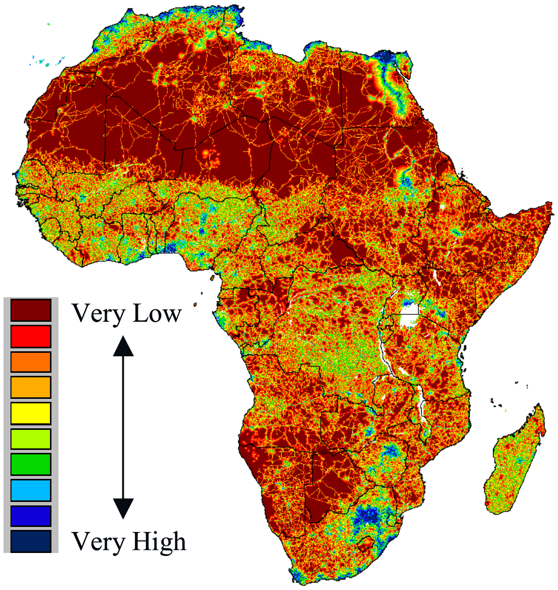
Wealth is an important factor in determining how well societies can cope with environmentally driven societal stress. Financial wherewithal provides individuals, institutions, and governments the capacity to address needs – through trade and commerce. Wealthy nations are in a better position to respond to shock events, and to accommodate natural vulnerabilities such as inadequate arable land or fresh water stock. Since sub-national data on income or wealth is not available, this project attempts to model its distribution using cartographic techniques reliant on reported national level gross domestic product statistics.



National level gross domestic product (GDP) purchasing power parity (PPP) is reported to the United Nations periodically according to agricultural, domestic, and industrial sectors. Other elements in the GIS provide spatial definition of these sectors. Agricultural regions are delineated using the IGBP Global Land Cover Characterization, with primeness providing a measure of land quality. Domestic and industrial regions are delineated using transportation infrastructure, persistent lights, and central place locations. Persistent light intensity and population density provide a measure of domestic and industrial intensity. Based on these delineations, national level GDP reports are geographically distributed and differentially allocated according to a heuristic based on the corresponding intensity level. The reported agricultural GDP is parsed to individual kilometers of agricultural land as a function of the modeled agricultural primeness. Reported industrial GDP is distributed to urban areas as captured by the lights at night data layer. Domestic GDP is distributed as a function of LandScan population density. The final map combines these layers into a total GDP for each square kilometer with each country.

Infrastructure Intensity

The extent of regional development provides a useful indicator of social resources available to create goods and services, distribute food, go to market, purchase raw materials, provide food aid to needy – essentially to support the functioning of a modern economic system. Such a measure is used in GI models to estimate a regions ability to bring domestically produced commodities to market and distribute imported food, and as a general indicator of social capacity. A geostatistical measure of development, termed "infrastructure intensity," has been extracted from information related to transportation, central places, and industry.



Infrastructure intensity is created by a cartographic model that defines the relative access of each square kilometer to central places and transport infrastructure. The model parameters consider proximity to rail, roads, and settlements. The relative density of the road and rail pattern also weights their proximity. For example, areas of multiple roads intersecting have a greater service potential than just two roads intersecting. Cities and settlement patterns are sorted by size into five different classes by area using a combination of lights at night and DCW settlement areas. Larger urban areas exert a greater and more highly weighted proximity effect than small settlements. The resulting surface portrays the relative accessibility to combined infrastructure. It is often useful to illustrate the location and proportion of population as a function of their ability to access the transport service structure and the relative capacity of that structure.

ESTIMATION OF RISK SURFACES

Core data and derived features were used in GI to estimate risk, capacity and likelihood surfaces. Risk surfaces describe food and water balance. The geospatial techniques for estimating water balance and food balance, two key risk surfaces, are described in the following.

Water Balance

A water balance model for Africa draws total average annual water demand from total average annual renewable water supply to estimate a regional scale watershed water balance. The spatial datasets address critical analysis questions, identifying by watershed throughout Africa the location and extent of

- renewable water supply
- water demand from industrial agricultural and domestic sectors
- water surplus and shortfall throughout the continent.
- the dependency of watersheds on inflow from exterior watersheds to meet local water demand

GI developed regional scale GIS models for the entire African Continent at one-kilometer resolution. Results were aggregated to USGS HYDRO1K Level 3 watersheds for regional scale analysis. Renewable water supply is derived from ESRI ArcAtlas 'Our Earth' groundwater discharge and runoff, and National Oceanic and Atmospheric Administration National Geophysical Data Center precipitation and evapotranspiration 1931-1960. The groundwater discharge layer is produced by weighting NOAA precipitation by the ESRI ArcAtlas groundwater discharge coefficient surface. evapotranspiration is subtracted from total precipitation, runoff and groundwater discharge to estimate total renewable water supply per square kilometer and by Level 3 Watersheds.

Water demand is derived from World Resource Institute (WRI) 1998 estimates of national water consumption for industrial, domestic and agricultural sectors. These sectors were mapped using NOAA DMSP night time lights and International Geosphere Biosphere Programme land use/land cover map databases, and the ORNL 1998 Landscan Population density product. Areas of persistent night time bright lights were identified to model industrial areas. These areas were modeled as industrial water demand centers. IGBP Land Use/Land Cover cropland and cropland/natural mosaic land cover areas were modeled as agricultural water demand centers. ORNL 1998 population was weighted by WRI national water consumption estimates to map domestic water demand. Total water demand is modeled as the sum of industrial, agricultural and domestic water demand.

A static water balance, showing water surplus and shortage without consideration of interwatershed flow is produced. Total water demand is subtracted from total water supply to derive static water balance. Next, interwatershed flow is modeled to produce an end-state water balance. The connectivity of watersheds is identified, and intershed water flow is programmed in a process GIS model. Throughout the course of flow, water balance is drawn down by local demand. End-state water balance shows water shortage and surplus where water has flowed through the drainage network and reached its final destination. Surfaces showing water supply, demand and balance normalized for watershed area were also produced. The surfaces addresses the critical question of identifying the location and extent of water supply, demand and balance at a regional watershed level. The total volume of water inflow to each watershed is also identified to show upstream dependency from exterior watersheds for water supply.

Food Balance

GI developed a supply/demand and balance approach to estimating regional food balance in Africa. A demand surface is subtracted from a supply surface to produce a food balance surface showing areas of food surplus and shortage. The food balance surfaces are based on figures contained in the Food and Agriculture Organization of the United Nations’ FAOSTAT database for 1998, the most current period that was available.

Food Supply. The food supply surface shows total food available, expressed in daily calories, per square kilometer. Supply is the total estimated calories for human consumption from food imports estimated domestic production. Since FAOSTAT data estimates commercial agriculture production, the food supply surface does not account for noncommercial agricultural production, such as subsistence agriculture.

Food Imports. The food imports surface is an allocation of national food import caloric estimates to a one-kilometer resolution suitability surface. Suitability for food import allocation is based on cost distance from major import centers, such as port cities, population density, and a weighted concentration of wealth surface. Food imports are derived by allocating FAOSTAT national estimates of 1998 food imports to an enhanced suitability surface. First, food import centers are identified. Major import locations are created from the CIA World Factbook and evaluation of 1998 ORNL population density, and DCW transportation infrastructure (major rail and road junctures). Next, a friction surface is produced that represents the cost of transporting food from import centers to demand areas. The friction surface assigns low cost to transportation infrastructure areas. High population density areas also receive a low cost designation. This reflects the economy of scale of supplying food to high population density centers. This friction surface is used to generate a cost distance surface from import centers. This surface shows the cumulative weighted distance of providing food from import centers. The cost distance surface is inverted to derive a suitability surface. The resulting surface shows the suitability of the landscape for food imports.

Before the suitability surface is created, the cost distance surface is modified by two factors. First, population density is applied to reduce cost distance. 1998 ORNL population is proportionally adjusted to tie to 1998 FAOSTAT national population totals. The cost distance surface is reduced proportionally to population. Highest population density areas receive greater cost reductions, while lower density population centers smaller cost reductions. This fosters allocation of food supply to heavy food demand areas. Second, a wealth factor is applied to the cost distance surface. This wealth factor uses GINI concentration of wealth estimates as well as disaggregated wealth to concentrate food in areas of higher wealth, and reducing food concentrations in areas of lower wealth. The GINI factor modifies the influence of wealth on the cost-distance surface. Thus, in areas of higher GINI coefficients (reflecting higher concentration of wealth), the impact of wealth is stronger on the allocation of food imports. Conversely, in areas of lower GINI coefficients (reflecting more even distributions of wealth), the impact of wealth is weaker on the allocation of food imports.

Population density and wealth are thus factored into cost distance to produce a suitability surface for food imports. In this surface, areas of high population density, high wealth, and low cost distance to food import centers will experience greater concentrations of food imports. Conversely, low density, isolated, lower wealth areas will experience lower concentrations of food imports. National food imports (daily calories) from the 1998 FAOSTAT database are allocated to the suitability surface to map a food import surface (total daily calories).

Domestic Food Production. The domestic food production surface shows the total daily calories available for food consumption from domestic production. Agricultural primeness (the suitability of the landscape for agricultural use) and a proximity to agricultural primeness surface is combined with disaggregated wealth and 1998 population density to model a distributed domestic food supply surface. The agricultural primeness surface is the suitability of the landscape for agricultural use described above. The suitability scores of physical and socio-economic criteria are combined to determine the agricultural primeness component. Higher agricultural primeness areas in turn receive higher suitability scores for domestic food production.

To distribute food supply from the point of production to the point of demand, additional proximity, wealth, and population density criteria are applied. The proximity criteria characterizes the 'nearness' of the landscape to areas of high agricultural primeness. Areas that are closest to areas of high agricultural productivity receive an increase in suitability for domestic food supply. Areas that are distant to centers of high agricultural productivity are assigned a lower suitability score than areas nearby.

The wealth criteria serves a similar purpose as in the food import component. The wealth factor uses GINI estimates as well as disaggregated wealth described previously to concentrate food in areas of higher wealth, and reducing food concentrations in areas of lower wealth. The GINI factor modifies the influence of wealth on the cost-distance surface. Thus in areas of higher GINI coefficients (reflecting higher concentration of wealth), the impact of wealth is stronger on the allocation of domestic food supply. Conversely, in areas of lower GINI coefficients (reflecting more even distributions of wealth), the impact of wealth is weaker on the allocation of domestic food supply. Lastly, 1998 ORNL population density, adjusted to tie to FAOSTAT population estimates is used to concentrate domestic food supply. Higher density population areas receive greater suitability for domestic food supply than low population density settlements. These agricultural primeness, proximity to agricultural primeness, wealth, and population density criteria are combined to develop an aggregate domestic food supply suitability surface. 1998 FAOSTAT national domestic food production (daily calories) are then allocated to the aggregate suitability surface to derive a domestic food supply surface (total daily calories). The total food supply surface is the sum of food imports and domestic food supply. It shows the total available food supply in daily calories from commercial agriculture, from imports and domestic production.

Food Demand and Food Balance. Two food demand scenarios are developed. The first scenario uses 1998 FAOSTAT national averages for daily caloric consumption. The national average food consumption is weighted by adjusted 1998 ORNL population density to develop a surface of food demand (average daily calories). The 1998

ORNL population is adjusted to match 1998 FAOSTAT figures for population totals. The second food demand scenario uses an average food consumption of 2,000 calories per day per person to generate a food demand surface.

Food balance is the aggregate difference between food supply and demand. The surface shows areas of food shortage and surplus throughout Africa, in total daily calories. Two scenarios are produced which present differing demand components. The first scenario models food balance based on 1998 national averages for daily caloric consumption.

The second food balance scenario models food balance by applying 2,000 calorie food consumption per day per person to the demand component. Many nutritionists consider 2,000 calories per day to be a standard for sustenance for non-a sedentary individual. The map databases illustrate how 2,000 calories per day represents an actual increase in caloric consumption for many African states. The map highlights areas which could experience food shortage in the event that all people consumed 2,000 calories daily, per country.

GI also developed food balance scenarios showing the impact of disruption of food imports. The maps show food balance where total food supply is based only on domestic production. The map database showing food balance without food imports, based on national average caloric consumption illustrates the magnitude of sensitivity of areas to food import interruption. The map databases showing food balance without food imports, at 2000 calories daily consumption, in particular shows areas that could mitigate interruption of food imports by reducing food consumption to 2,000 calories per capita per day.

CONCLUSIONS

The Geospatial Indicators Global Database effort has integrated a diverse collection of open source scientific data about natural and human environments in a harmonized structure, with common geographic projections, for all the developing nations of the world. Core data from extant sources were used to generate innovative derived features that were use in GI modeling to create security risk and likelihood surfaces, elsewhere reported to correlate with food emergency events in continental Africa. The intent of producing such a unified database is to support the modeling and identification of regional patterns and trends, rather than to provide specific details or accurate measures at the scale of individual pixels. To this extent, GDB has proved most useful. Examining regional patterns that are revealed through analysis of disparate information layers can lend new insights into ways one can monitor and evaluate natural dynamics, human behaviors and social responses resolved to better than national scale.

The development of environmental and human features for the terrestrial and ocean surfaces of the Earth is an ongoing and growing enterprise. For example, several MODIS based global vegetation indices are constructed routinely at spatial scales of 0.25 to one-kilometer resolution. Efforts to develop improved terrestrial products of human features, such as population density, infrastructure health and economic factors, introduce additional complexities, as some of these data lend themselves better to articulation in terms of administrative units (vectors) instead of pixels. While the availability of such data is a boon to science and research, technical barriers may limit joint use and utility of diverse data.

The construction of Geospatial Indicators GDB, though mostly straightforward and somewhat routine, required intensive effort of GIS professionals to deal with the myriad of technical problems encountered. Dissemination of the result, while desirable, faces contentious property right, economic and technical issues. To this point, one year after the initial development of GDB, broad and general dissemination of the product is unresolved. Even the growing presence of standards does not generally guarantee that the resultant data automatically fits with other data sets, as requirements specific to other projects change the format, scale, projection, and other technical factors affecting the end product. Lack of access to such data in an integrated form is a hindrance if not barrier to the development of other novel scientific research, especially where GIS and imagery expertise are less available to researchers whose primary interests are in natural or human phenomenology and mechanics, not data models of terrestrial features and related data collection systems. Further development of standards that provide for more direct joint use of the growing array of scientific data is certainly an appropriate direction. Meanwhile, the development of data collections similar to this and the USGS Global GIS will fill an important niche.

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