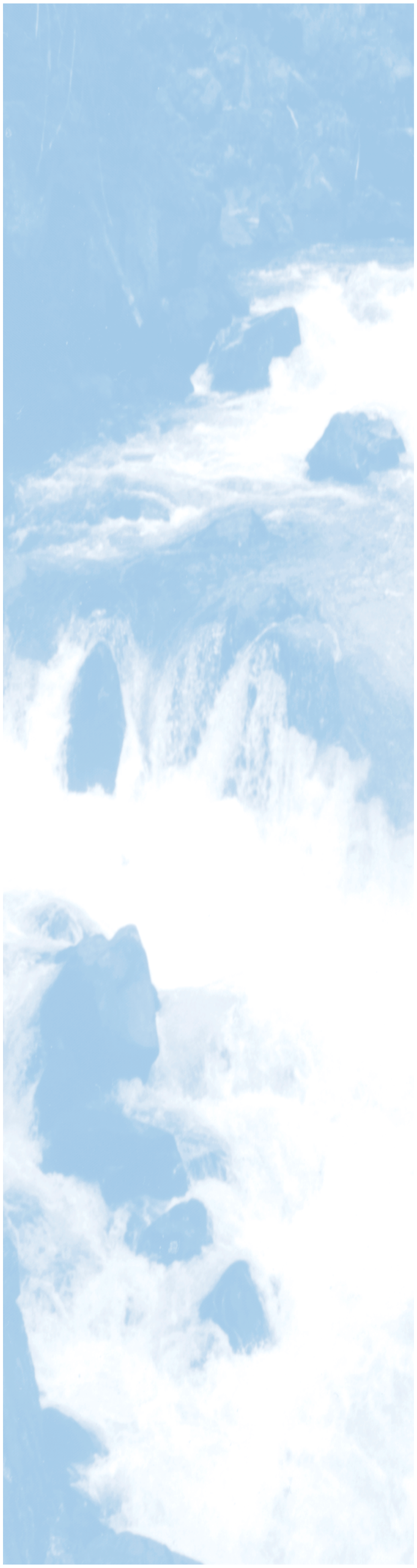

Thematic Maps: Visualizing Spatial Variability and Shared Benefits

Spatial variability is at the heart of geography, a field dedicated to understanding where things are and why. It is also a critical component in understanding many complex systems, particularly those which include interactions between wildly disparate sets of forces.

Water systems, for example, can act as a powerfully unifying resource, so it is ironic to the point of absurdity that water education, management, and discourse are so fragmented. To truly assess water resources in their most holistic sense, one needs to include the many aspects of the hydrologic cycle, from meteorology to surface hydrology to soil sciences to groundwater to limnology to aquatic ecosystems. And that is just the physical system. One should also have an integral sense of the human dimensions, from economics to law to ethics to aesthetics to sociology and anthropology. Universities and management institutions are simply not organized along these lines; often they are fragmented to the point where even surface water and groundwater, quality and quantity, are separated out as if they were not inextricably inter-related.

Fortunately, nature has given us a unit for analysis in which all of these components coalesce — the river basin.[1] Unfortunately, many analysts have a tendency to ignore this hydro-centric unit, especially when including socio-economic or geo-political variables, in favor of units for which one can actually find data, notably the nation-state.[2] The fact that water resource issues manifest themselves within basins, while analyses are often based on country boundaries, can lead to fundamental misunderstandings. Take, for instance, the most widely cited measure for water resources management — Malin

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[1] A "river basin" is defined as the area which contributes hydrologically (including both surface- and groundwater) to a first order stream, which, in turn, is defined by its outlet to the ocean or to a terminal (closed) lake or inland sea. Thus, "river basin" is synonymous with what is referred to in the US as a "watershed" and in the UK as a "catchment."

[2] A useful exception is Revenga, C., S. Murray, J. Abrams, and A. Hammond. *Watersheds of the World* (Washington, DC: World Resources Institute, 1998), which describes 15 biophysical variables for 145 of the world's major river basins.

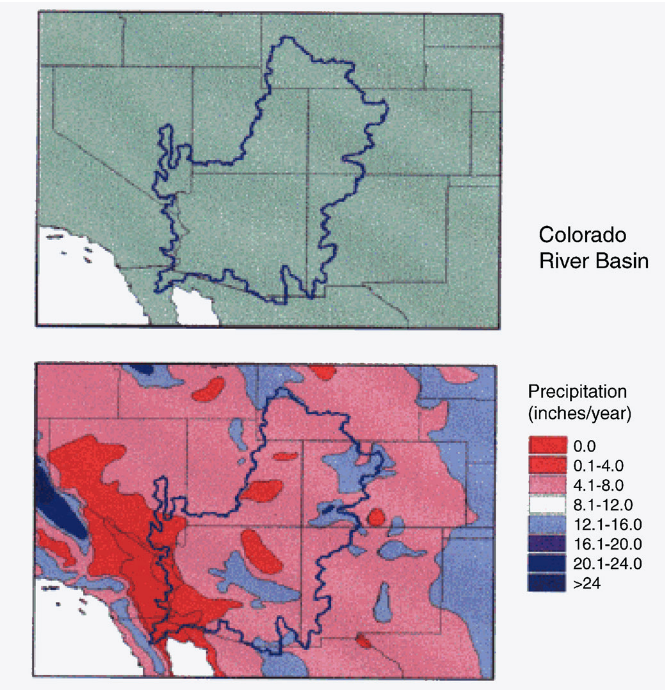


Figure 4. Spatial variation.

Falkenmark's (1989) Water Stress Index. This index, which divides the volume of available water resources for each country by its population, was originally only meant for preliminary, comparative purposes. Yet, as with many elegant measures, it has taken on a life of its own, often pointed to in security studies as an indicator of future conflict.

The top of Figure 4 shows a river basin shared by two nations, neither of which is particularly "water stressed," at least if assessed on a national basis. Yet, as presented in the lower figure, when we break down the data by basin and further include spatial variability (in this case, of precipitation), we obtain a much more accurate picture of the stresses in the lower Colorado River, shared by the United States and Mexico.

By superimposing several different data sets within a Geographic Information System (GIS), unified by the river basin, one can often increase understanding of the complex systems at work. Figure 5, for example, superimposes Ohlsson's Social Water Stress Index ("water stress" essentially weighted for level of economic development by a factor based on UNDP's Human Development Index), in the middle layer, over topography (which shows where the headwaters, dam sites, and agricultural land all lie), on the bottom layer, for the Ganges-Brahmaputra basin. These two data layers alone allow us to visualize representations of interactions between the location of headwaters, economic development, national water scarcity, likely dam sites and agricultural land and, perhaps as a result of these interactions, allow us to gain some insight into each basin country's vote in the UN General Assembly on the 1997 Convention on the Law of the Non-Navigational Uses of International Watercourses (represented in the top layer).

What does this have to do with treaties? What one notices in the global record of water negotiations is that many begin with parties basing their initial positions in terms of rights — the sense that a riparian is entitled to a certain allocation based on hydrography or chronology of use. Up-stream riparians often invoke some variation of the Harmon Doctrine, claiming that water rights originate where the water falls. Down-stream riparians often claim absolute river integrity, claiming rights to an undisturbed system or, if on an exotic stream, historic rights based on their history of use.

In almost all of the disputes that have been resolved, however, particularly on arid or exotic streams, the paradigms used for negotiations have not been 'rights-based' at all — neither on relative hydrography nor specifically on chronology of use — but rather 'needs-based.' 'Needs' are defined by irrigable land, population, or the requirements of a

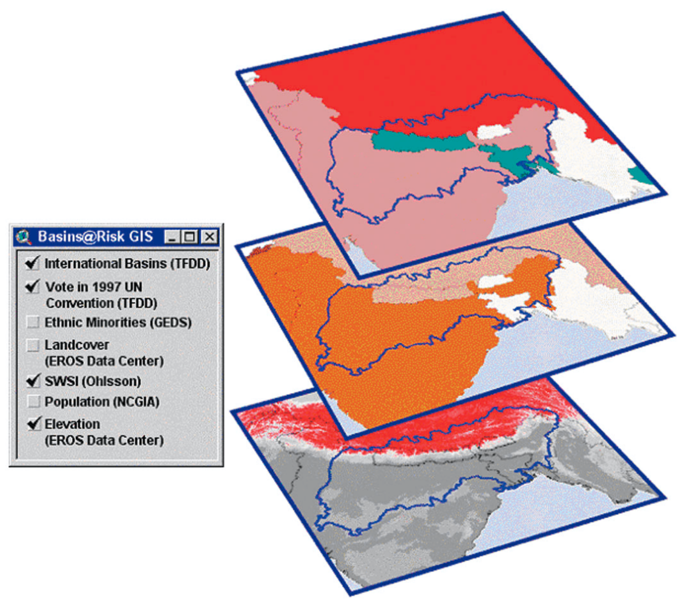


Figure 5. GIS and visualization: from bottom to top — topography, social water stress index, and country votes on 1997 UN Convention. Green states voted "yes," red voted "no," pink "abstained," and states in white were absent.

specific project. Occasionally, rare agreements go beyond 'needs' to 'interests' — the underlying incentives which influence individual and political behavior, such as the political capital gained through addressing a particular set of constituents' water issues.

In other words, the process of conflict resolution involves understanding the characteristics of a basin, in all of its bio-physical, socio-economic, and geo-political complexity, and then identifying the potential for positive-sum solutions based on the disparate interests of each party. Occasionally, this comprehensive approach has allowed riparians to move beyond looking at water as a commodity to be divided – a zero-sum, rights-based approach – and rather to develop an approach that equitably allocates not the water, but the benefits derived therefrom – a positive-sum, integrative approach, as seen below:

- Agreements developed under the Boundary Waters Agreement between Canada and the United States of America, for example, allocate not water, but equal benefits, usually defined by hydropower generation and flood control. This allocation of benefits results in the seemingly odd arrangement that power may be exported out of the basin for gain, but the water itself may not. In the 1964 treaty on the Columbia, an arrangement was worked out where the United States paid Canada for the benefits of flood control and Canada was granted rights to divert water between the Columbia and Kootenai rivers for hydropower. The relative nature of "beneficial" uses is exhibited in a 1950 agreement on the Niagara, which provides a greater flow over the famous falls during the "show times" of summer daylight hours, when tourist dollars are worth more per cubic meter than the alternate use in hydropower generation.

Iron Creek Falls, Columbia River tributary. Photo credit: Bryan P. Bernart.

- In 1957, the creation of the Mekong Committee for Coordination of Investigations of the Lower Mekong Basin was the first example of UN involvement in a program to develop an international river basin. The new Mekong Agreement was signed in 1995, after a relatively short period of negotiation benefiting from a shared data base, long-established relationships, and the familiarity of the key players

American Falls of Niagara River (left). Photo credit: Camille Freitag. Garganta del Diablo in Iguazu Falls. Photo credit: Rolando León.

Columbia River tributary. Photo credit: Bill Anderson.

with the provisions of relevant international jurisprudence. The Mekong Agreement clearly states the mutual commitment to cooperate. It establishes the Mekong River Commission as the international body that implements the Agreement and seeks cooperation on all aspects of water management.

- Despite three wars and numerous skirmishes since 1948, India and Pakistan, with World Bank support, have managed to negotiate and implement a complex treaty on sharing the waters of the Indus River system. The Indus Water Treaty was finally signed in 1960. During periods of hostility, neither side targeted the water facilities of the other nor attempted to disrupt the negotiated arrangements for water management.

- The political will to achieve a basin-wide agreement and framework for long-term cooperation on the part of the ten Nile Basin riparian states is gathering momentum. In 1992, representatives of all ten states agreed upon a Nile River Basin Action Plan, with the task of developing a cooperative scheme for the management of the Nile. In 1995, the World Bank, together with UNDP and the Canadian International Development Agency, accepted the request from the Nile riparian states to give impetus to the project. In 1999, the Nile Basin Initiative was launched, with the participations of all the basin states. The international community has facilitated an ongoing dialogue between the riparians of the Nile Basin, to develop a process of joint planning and institutional capacity-building.

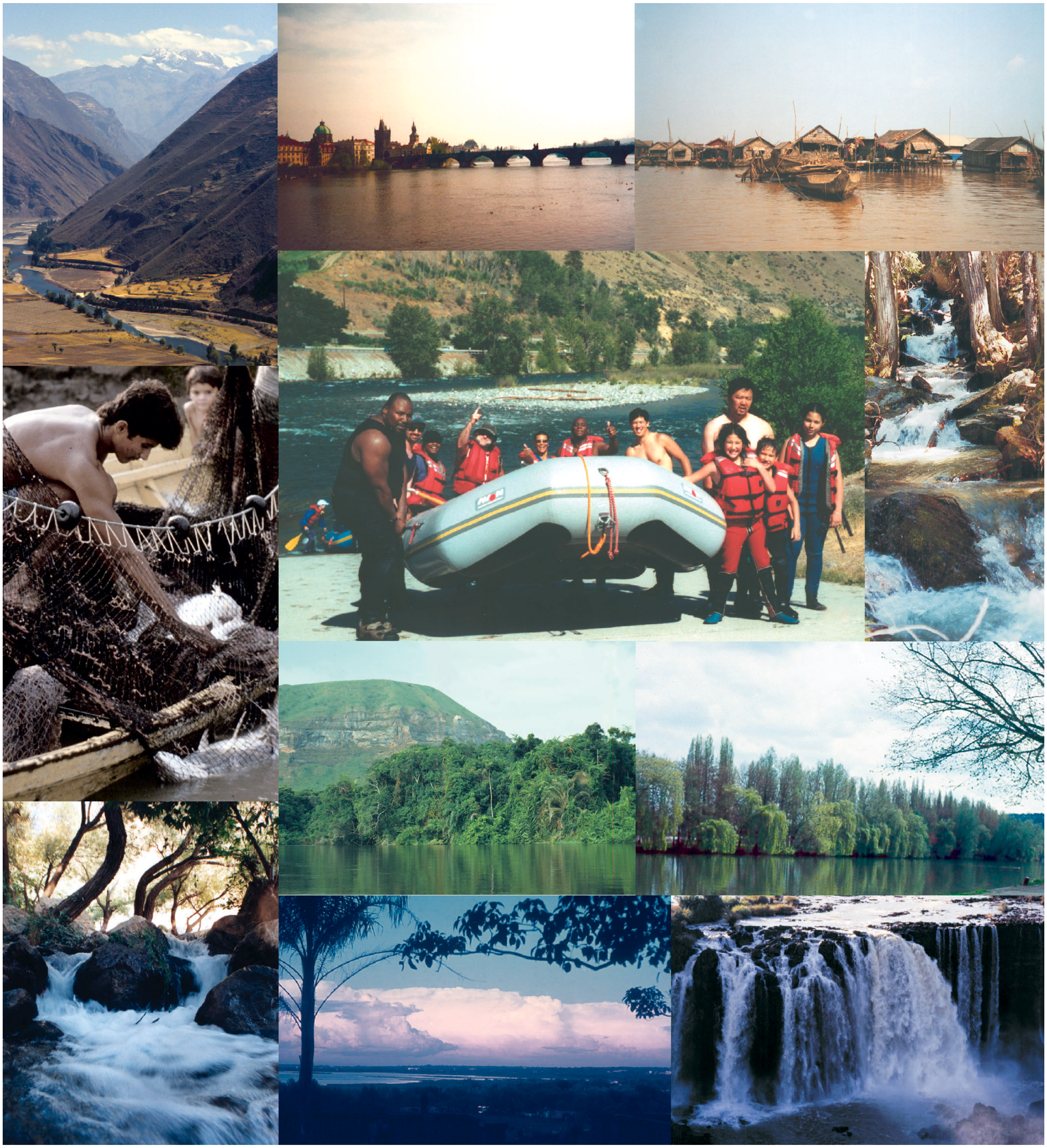
- The Danube Convention is a vital legal continuation of a tradition of regional management along the Danube dating back 140 years. As a document, it provides a legal framework for integrated watershed management and environmental protection along a waterway with otherwise widespread potential for disputes. The Environmental Program for the Danube River is also a basin-wide international body that actively encourages public and NGO participation throughout the planning process. This proactive stakeholder participation may help preclude future disputes both within countries and as a consequence, internationally.

- Even while Israel and Jordan were legally at war, Israeli and Jordanian water officials met several times a year at so called "Picnic Table Talks." As a result, when the Jordan-Israel Peace Treaty was signed in 1994, it was possible to include a well-developed annex acknowledging that, "water issues along their entire boundary must be dealt with in their totality."

Part of the process of identifying options for joint gains is "simple" visualisation. One needs to be able to see both the spatial diversity of the problems, and the unifying forces of the watershed to be able start to comprehend mutually beneficial trade-offs. To that

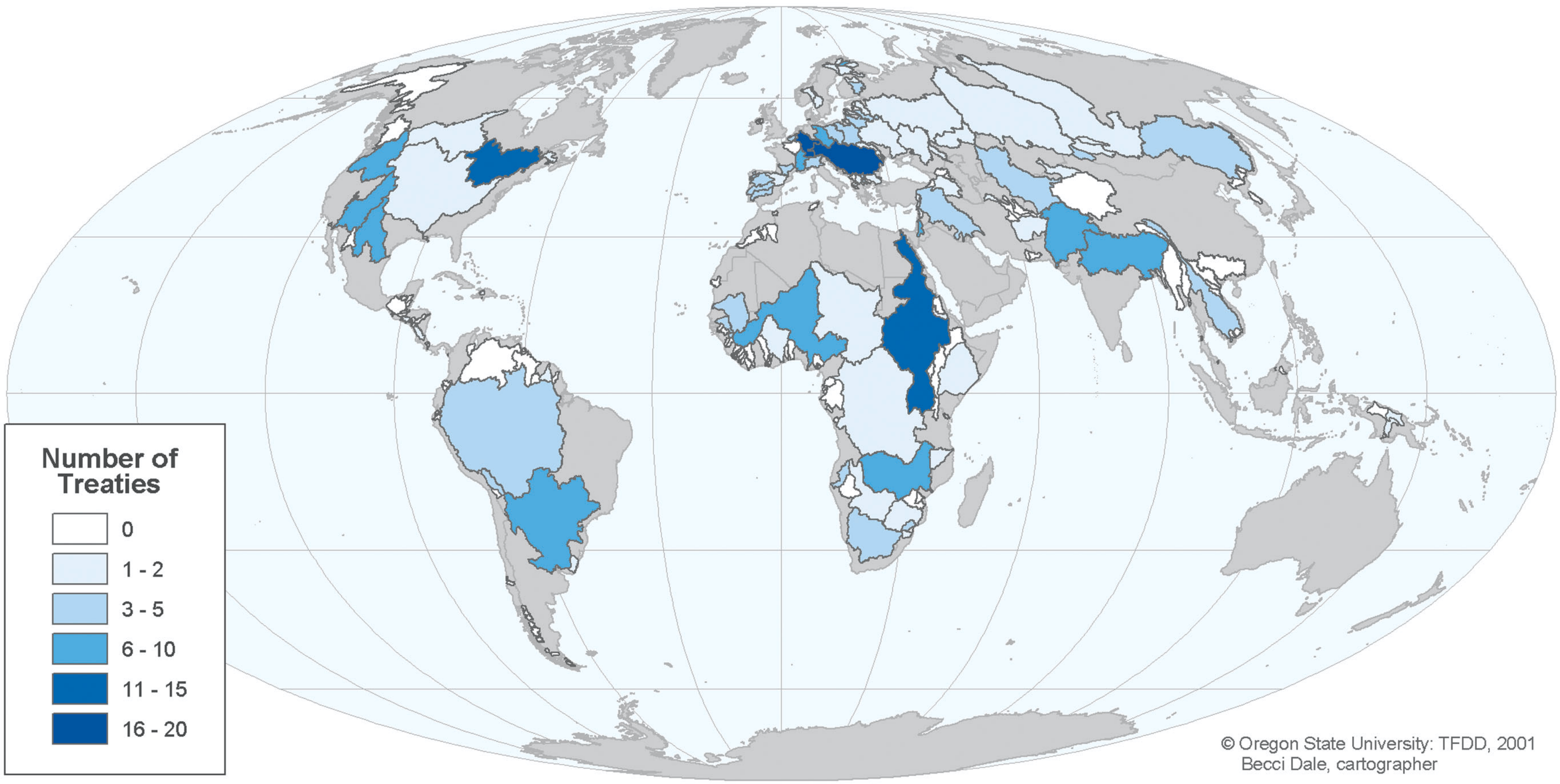
Tigris River tributary. Photo credit: Babak Sedighi.

end, we include the following thematic world maps. These ten maps, which include some traditional hydrologic data, and some less-traditional (as well as less hydrological), are broken down spatially but unified by one delineation — the international river basin. It is our hope that, by seeing sometimes familiar information within these new delineations, these maps may help spark some new approaches to a problem as old as history — how do we share this critical resource on which everything we do relies?



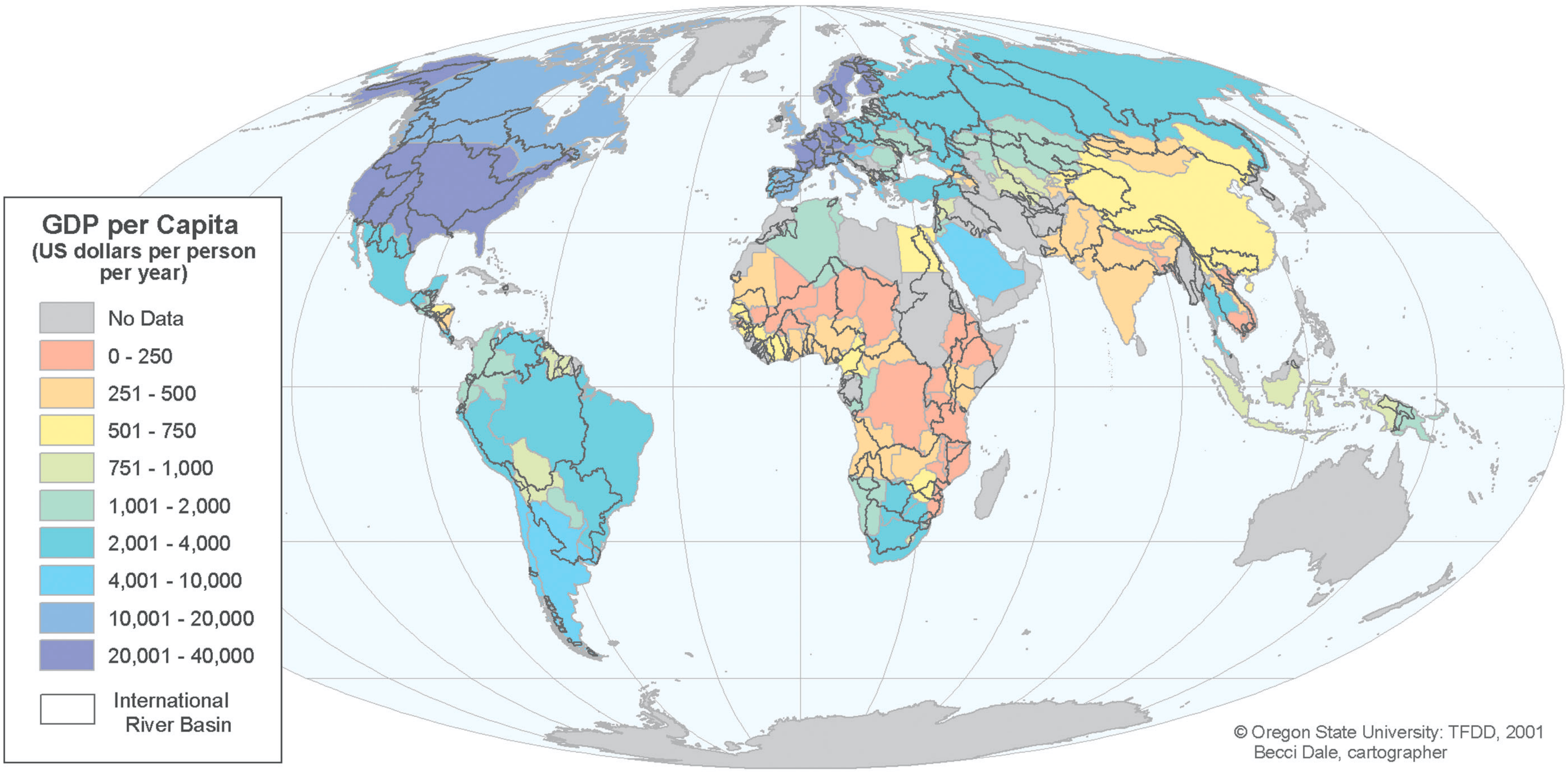
Clockwise, from top left: Urubamba River (M. Giordano); Vltava River (S. Yoffe); Tonle Sap (M. Giordano); Entiat River (T. Davis); Meuse River (B. Miraglia); Blue Nile River (B. Bishaw); La Plata River (R. León); Tigris River tributary (B. Sedighi); Amazon River (G. Bracher). Center: Wenatchee River (T. Davis); Congo/Zaire River (D. Thomas).

Number of Agreements per International River Basin



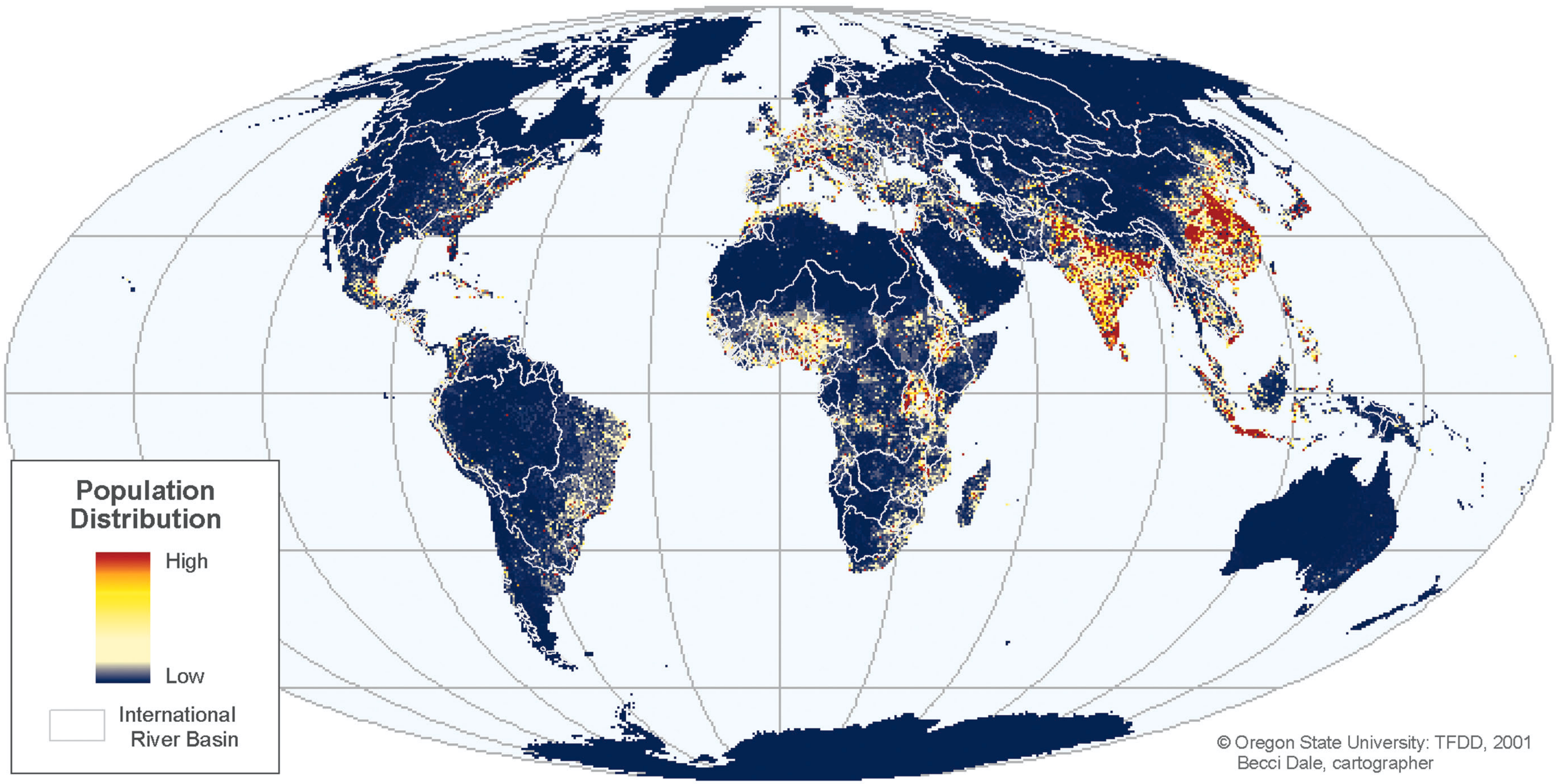
Data source: Treaties- Wolf (1999b).

Gross Domestic Product per Capita



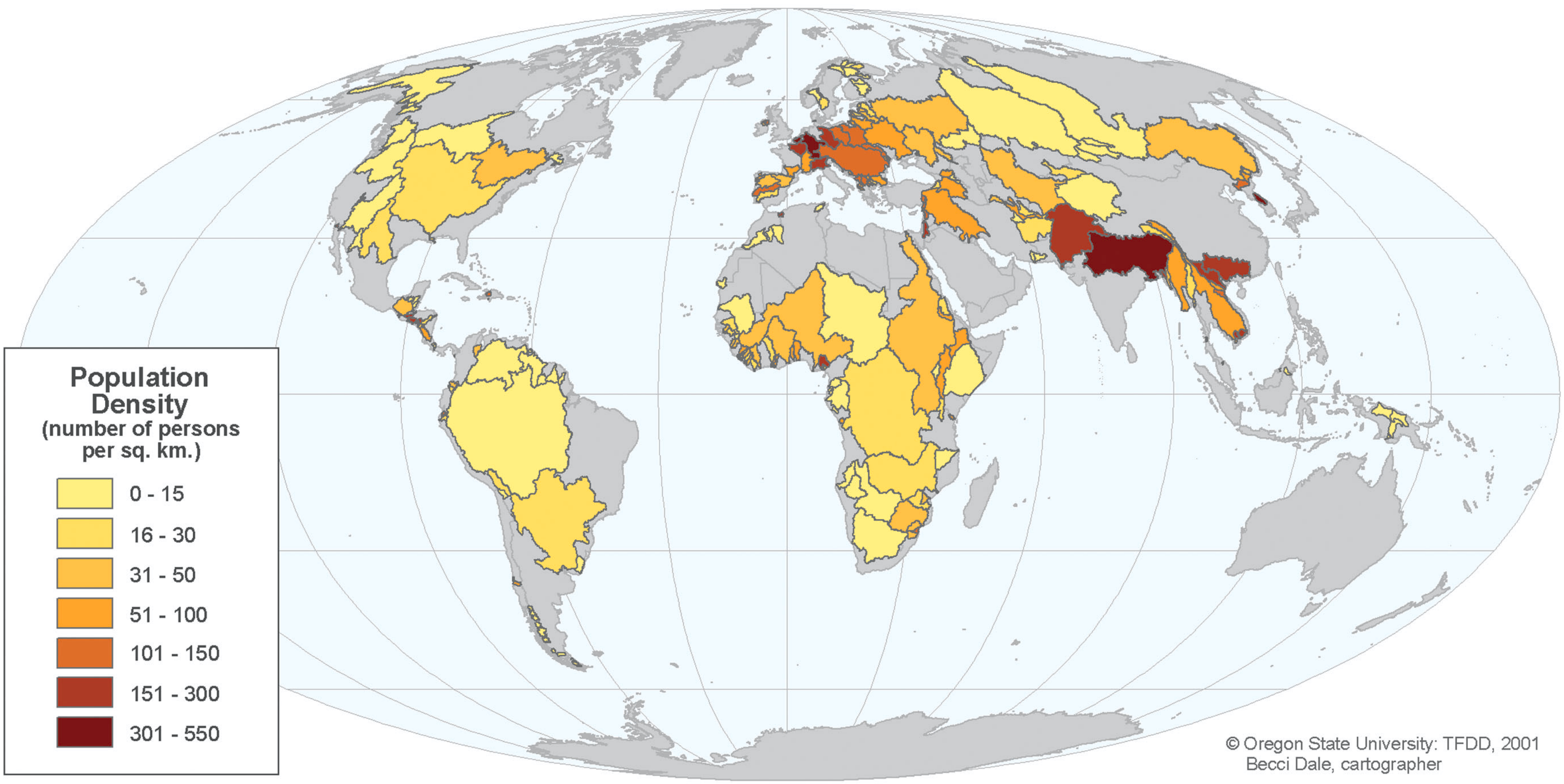
Data source: GDP- World Resources 1998-1999 Database (1998).

Population Distribution



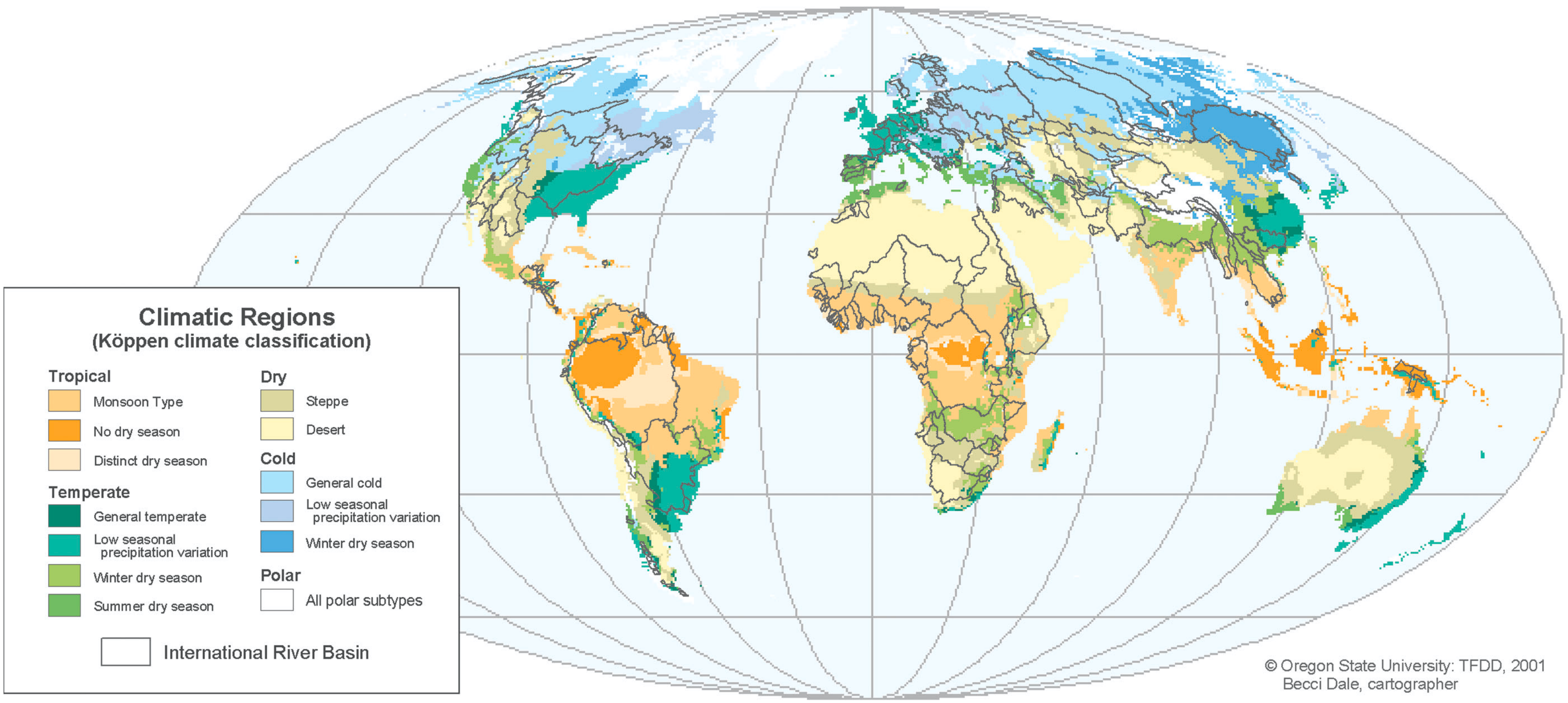
Data source: Population- Dobson et al. (2000).

Population Density per International River Basin



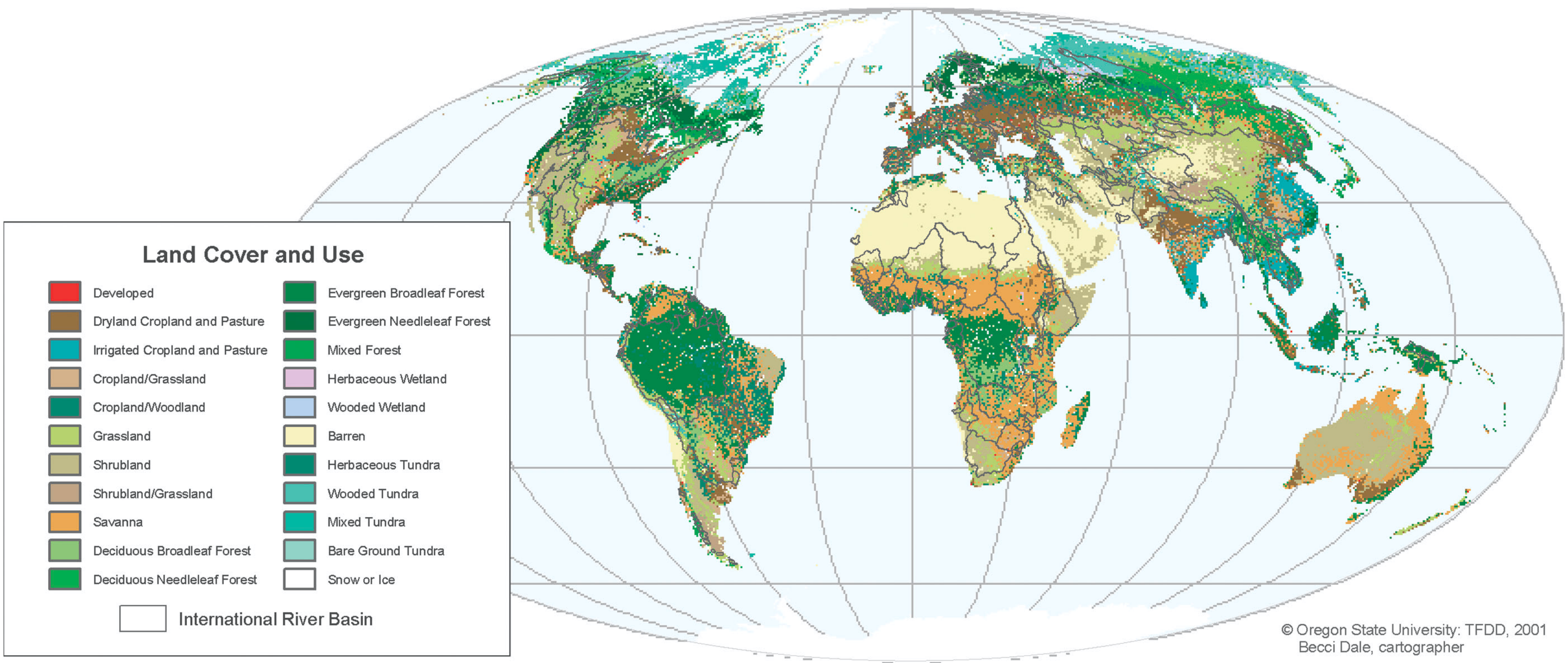
Data sources: Population- Dobson et al. (2000); Density by basin- Fiske and Yoffe (2001).

Climatic Regions



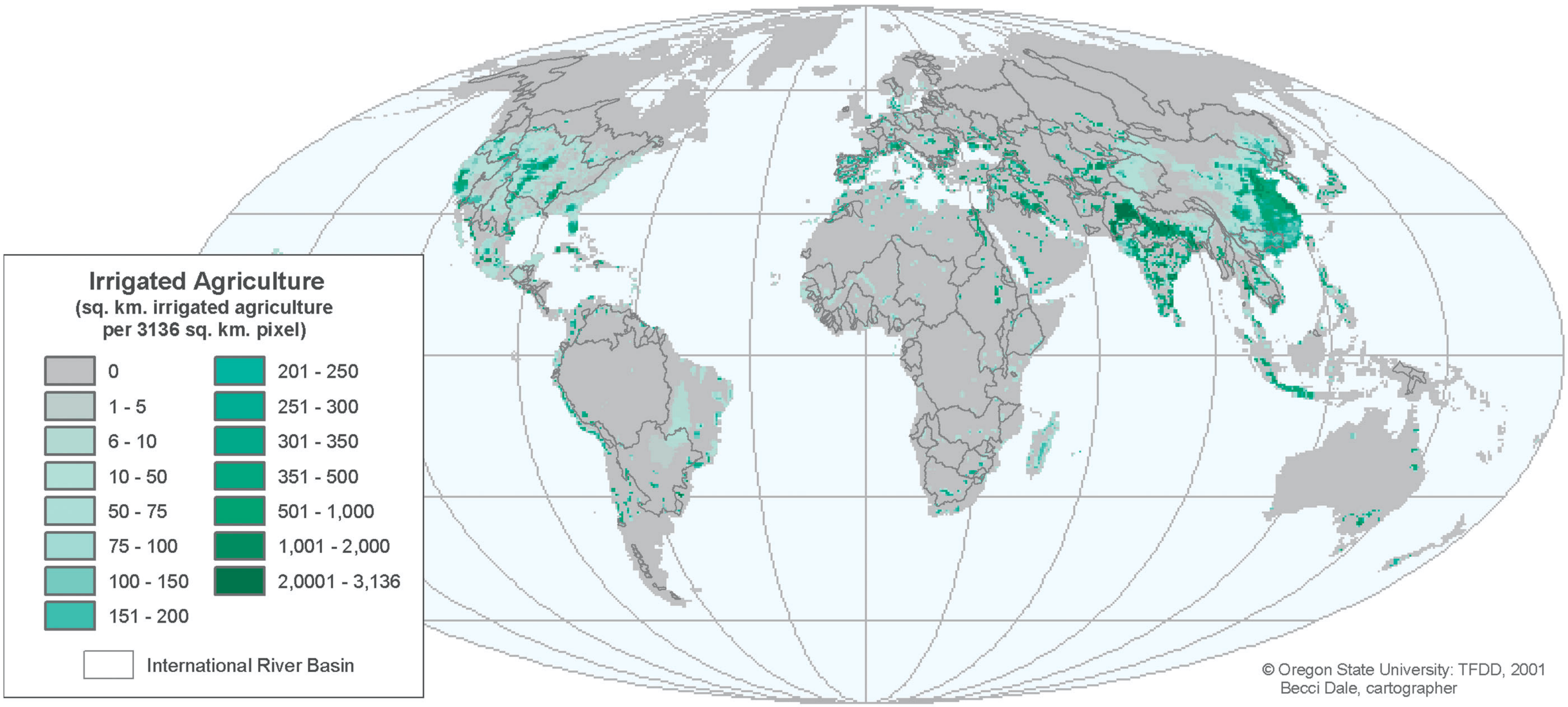
Data source: Köppen climate zones- FAO-SDRN Agrometeorology Group (1997).

Land Cover and Use



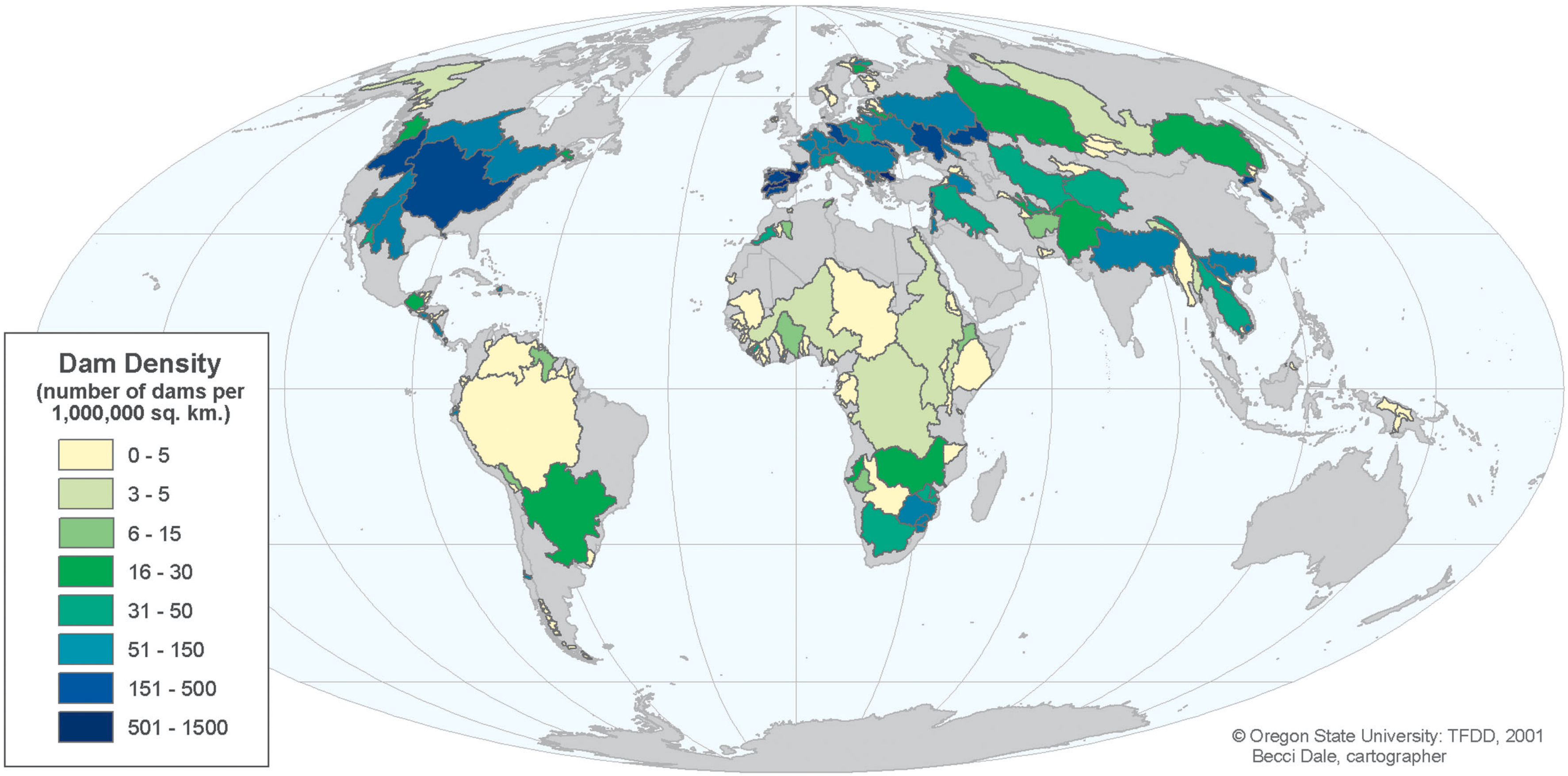
Data source: Land cover and use- United States Geological Survey (USGS), the University of Nebraska-Lincoln (UNL), and the European Commission's Joint Research Centre (JRC) (1997).

Irrigated Areas, circa 1995



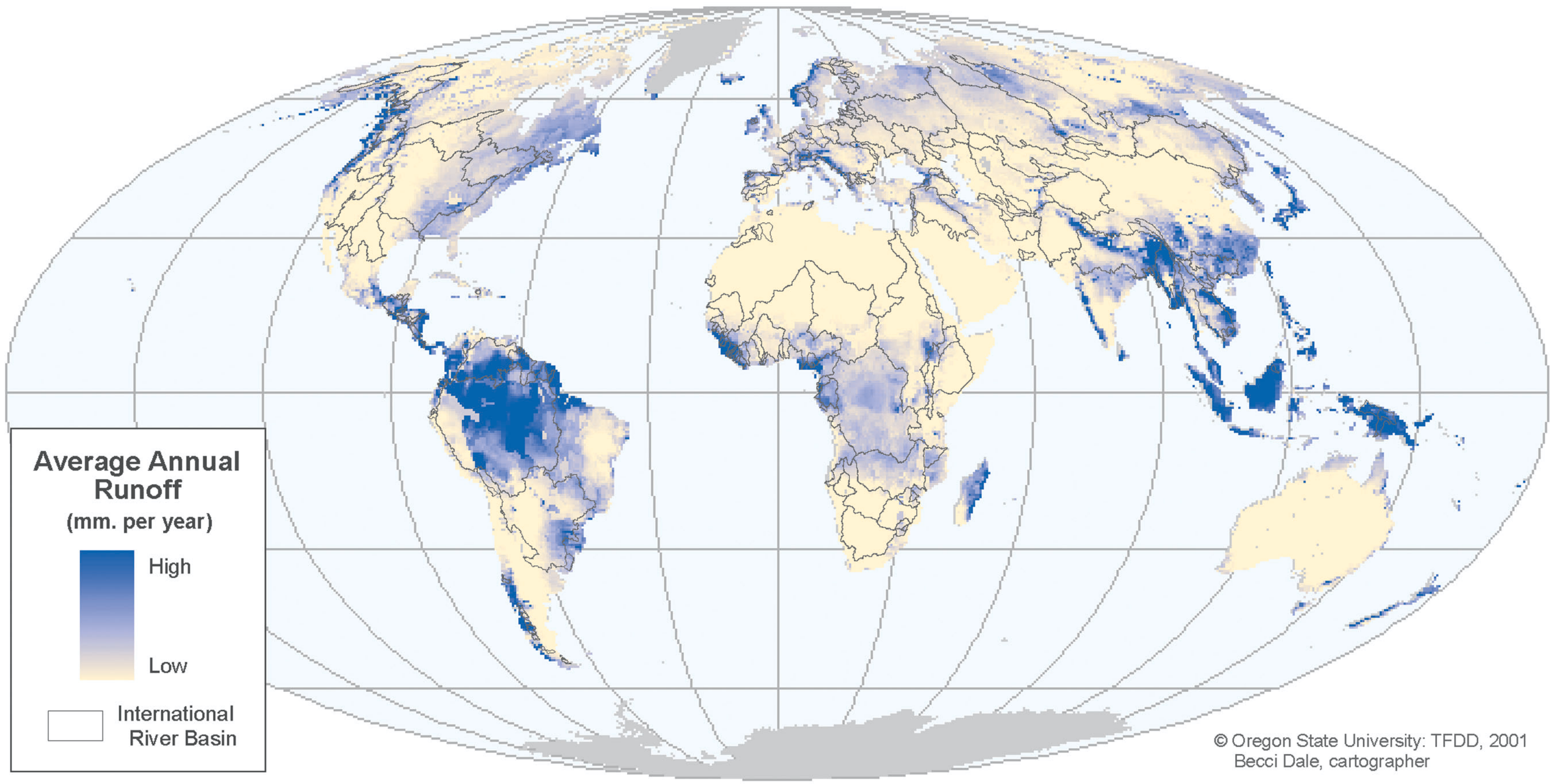
Data source: Irrigated agriculture- Döll and Siebert (2000), Siebert and Döll (2001).

Dam Density per International River Basin



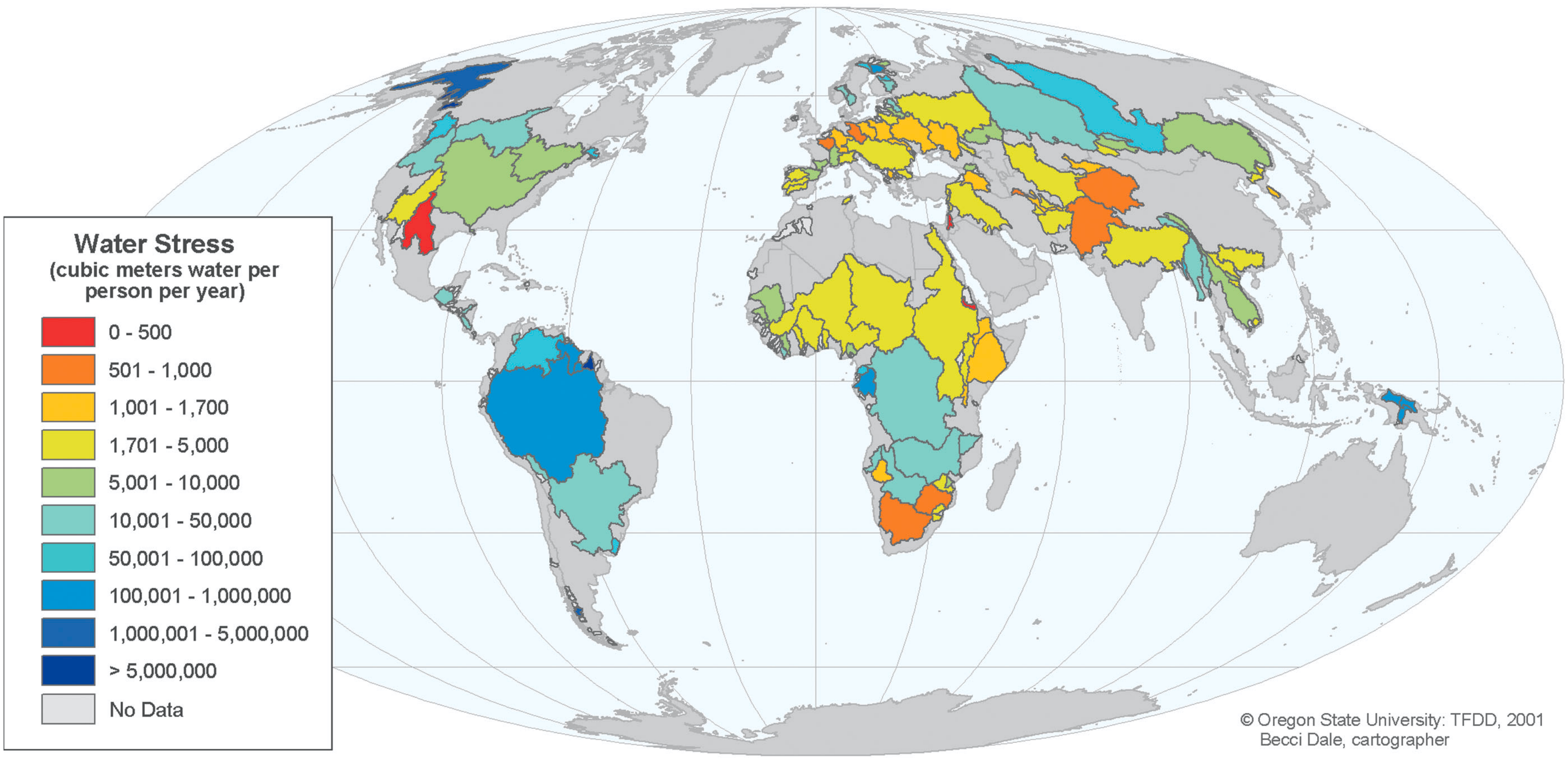
Data sources: Dams- Ph.D. Associates Inc. (1998); Density by basin- Fiske and Yoffe (2001).

Average Annual Runoff



Data source: Runoff- Fekete et al. (2000).

Water Stress per International River Basin



Data sources: Runoff- Fekete et al. (2000); Population- Dobson et al. (2000); Water stress by basin- Fiske and Yoffe (2001).