Tradeoff analysis between economic development and climate change adaptation for the Nile basin water resources

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Do tradeoffs exist between economic development and climate changes adaptation strategies?

- Evidence of climatic change impacts on the Nile basin people's way of life and economic development
- Unique climatic and socio-economic characteristics of the Nile basin history, current, and future
- Data action plan (data sharing, and Nile Basin hydro, climatic, and socio-economic data bank)
- Integrated physical and socio-economic modeling framework
- Tradeoff analysis model
- Case study – water entering Egypt; lessons learned, and revisited the research question – do tradeoffs exist?

Tradeoff analysis is a component of economic development process

Strategic Planning

Vision of work

Statements of work

Economic Development plans

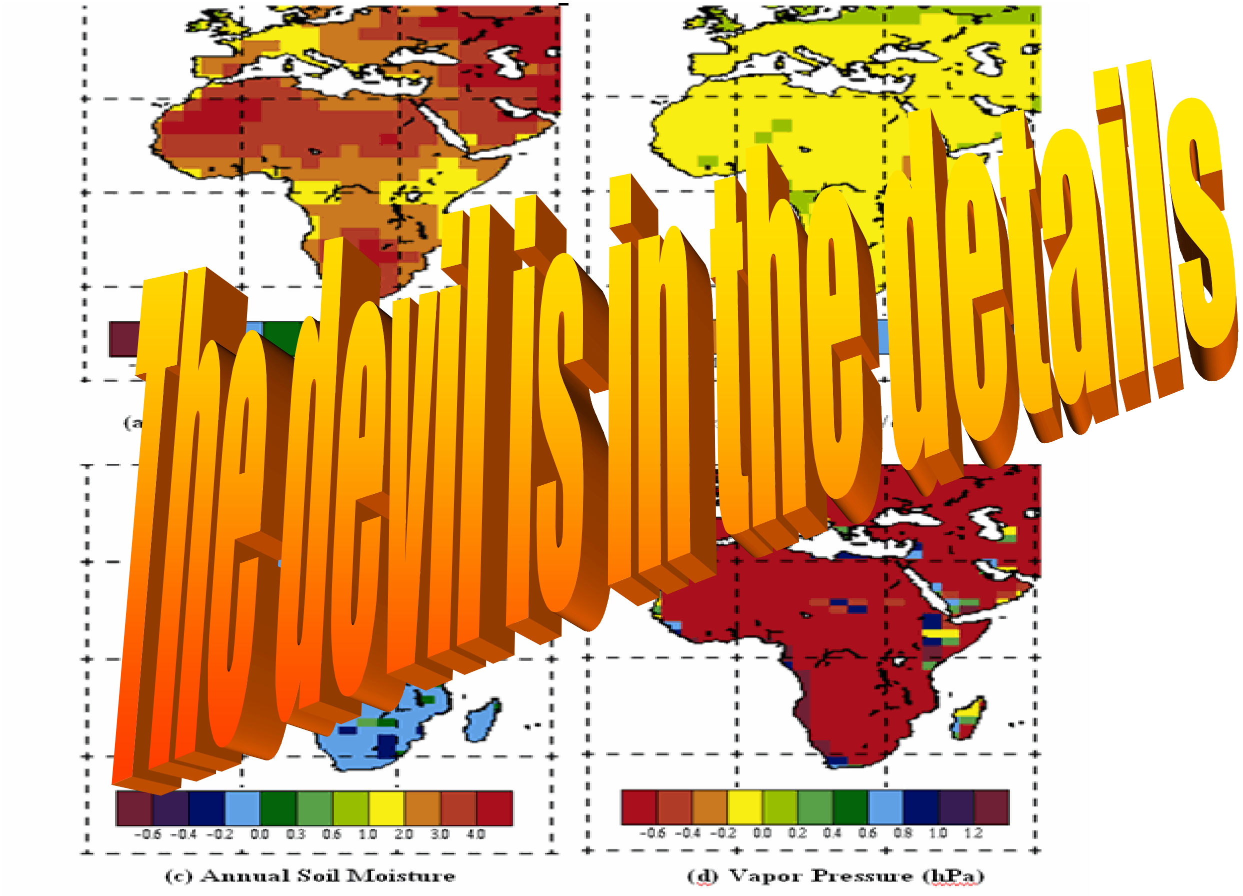
Strategic Coordination

Agreements

Implementation

Economic and Environmental tradeoffs

Evidence of climatic change: GCMs Scenarios by IPPC special reports



Source: IPPC Special Report on Emission Scenarios (SRES)
http://www.grida.no/climate/ipcc/emission/ visited April, 2008

Sand Storm in Sudan Khartoum 2004, by jorgenlindahl, Google Earth

Example of findings from Yates and Strzepek Studies

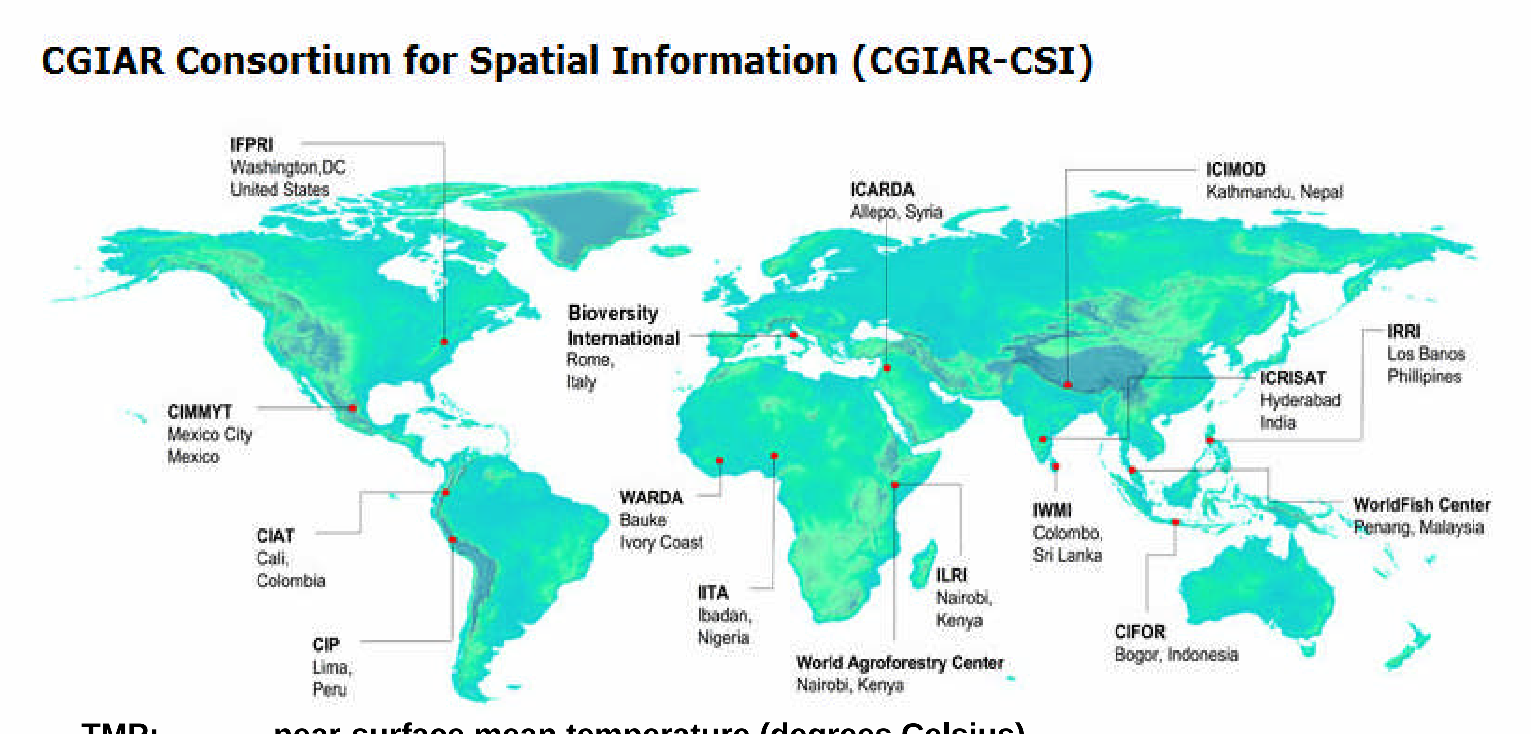
Climate, water availability and use, and economic implications are strongly related in the Nile Basin countries. Strzepek *et al*. (1995) estimated that infrastructure development, improved agricultural technology, and irrigation might mitigate **7-8%** of the agricultural impacts of climate change.

Yates and Strzepek (1996) found that including or excluding certain biophysical sectors and world markets influenced the development path and the nature of the autonomous adjustments. **The importance of a particular biophysical sector or of world markets was also dependent upon the specific climate change scenario.**

Strzepek *et al*. (2001) argued for significant links between the water reduction due to climate change and **socio-political-economic implications.**

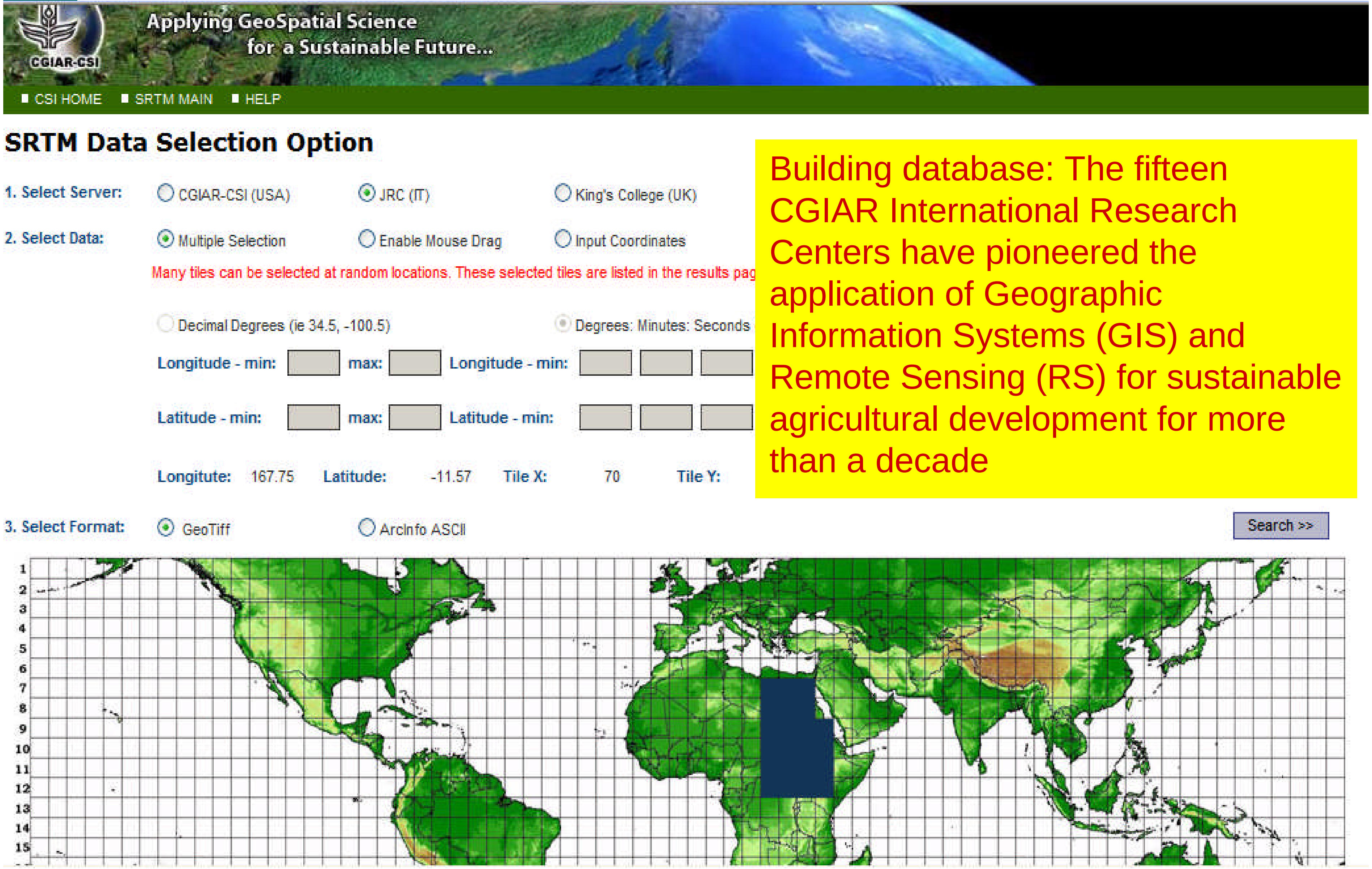
We lack well-designed, Nile basin specific models or modeling frameworks integrating **climate change impacts, hydrological system characterization, and economic development indicators.**

Climatic Data example from Consultative Group on International Agricultural Research CGIAR -CSI



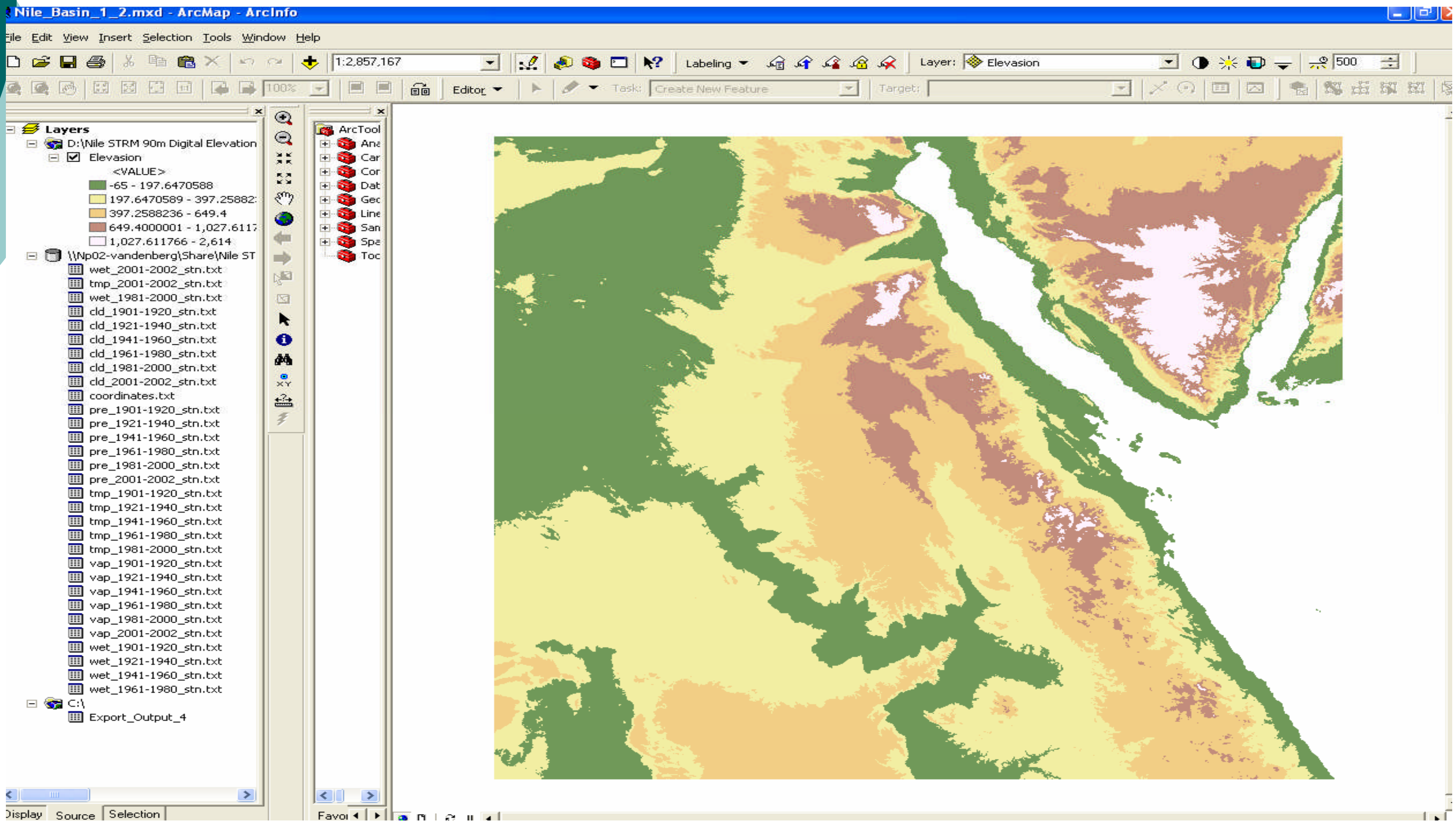
TMP:	**near-surface mean temperature (degrees Celsius).**
TMN:	**near-surface minimum temperature (degrees Celsius).**
TMX:	**near-surface temperature maximum (degrees Celsius).**
DTR:	**near-surface diurnal temperature range (degrees Celsius).**
PRE:	**precipitation (mm).**
WET:	**wet day frequency (days).**
FRS:	**frost day frequency (days).**
VAP:	**vapour pressure (hPa).**
CLD:	**cloud cover (percentage).**

Geo-spatial Climatic Data

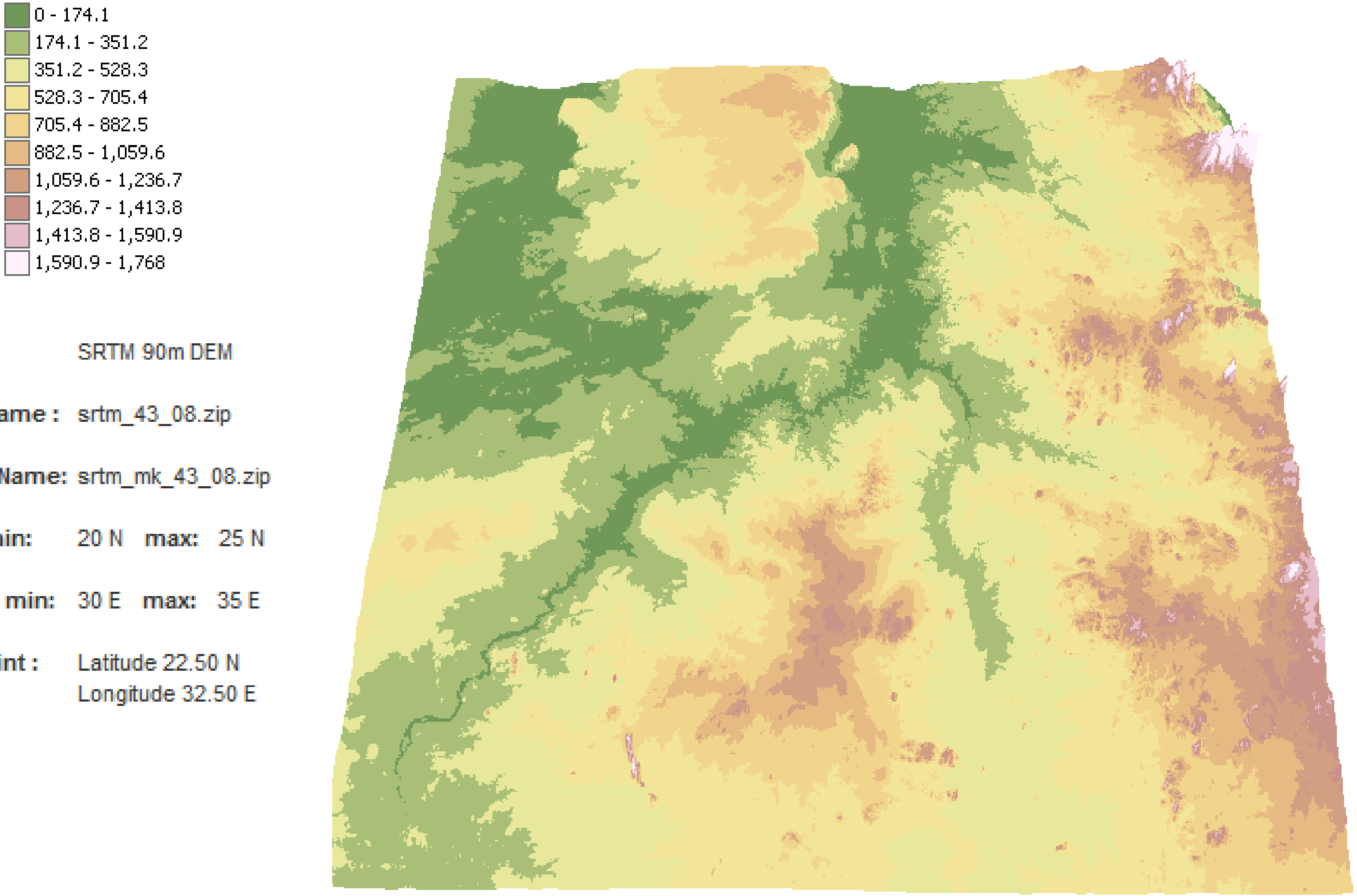


Building database: The fifteen CGIAR International Research Centers have pioneered the application of Geographic Information Systems (GIS) and Remote Sensing (RS) for sustainable agricultural development for more than a decade

Building climatic data bank



Data – Selected Site – water entering Egypt



Product : SRTM 90m DEM

Data File Name : srtm_43_08.zip

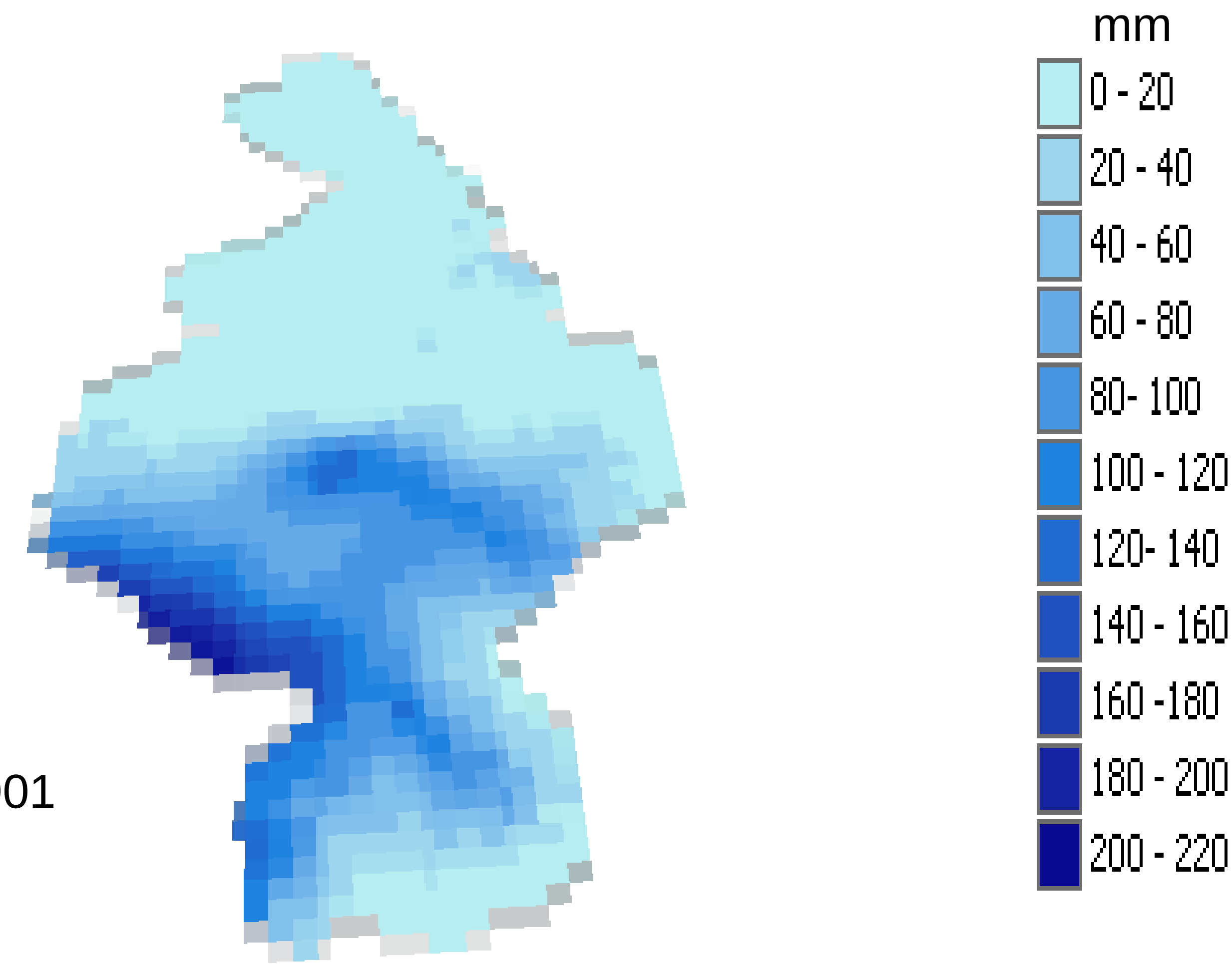
Mask File Name: srtm_mk_43_08.zip

Latitude min: 20 N **max:** 25 N

Longitude min: 30 E **max:** 35 E

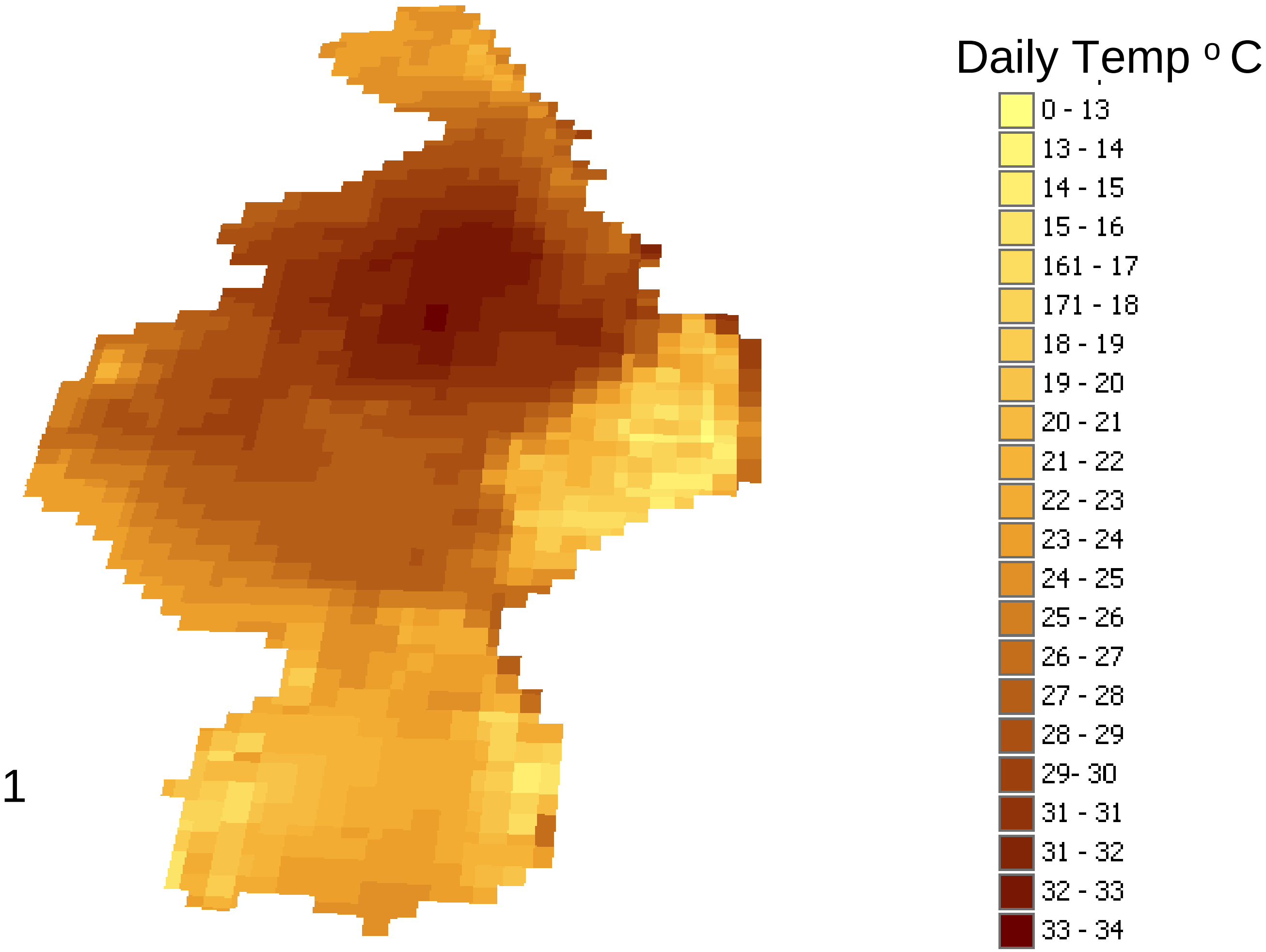
Center point : Latitude 22.50 N
Longitude 32.50 E

Database visualization example: precipitation throughout the basin



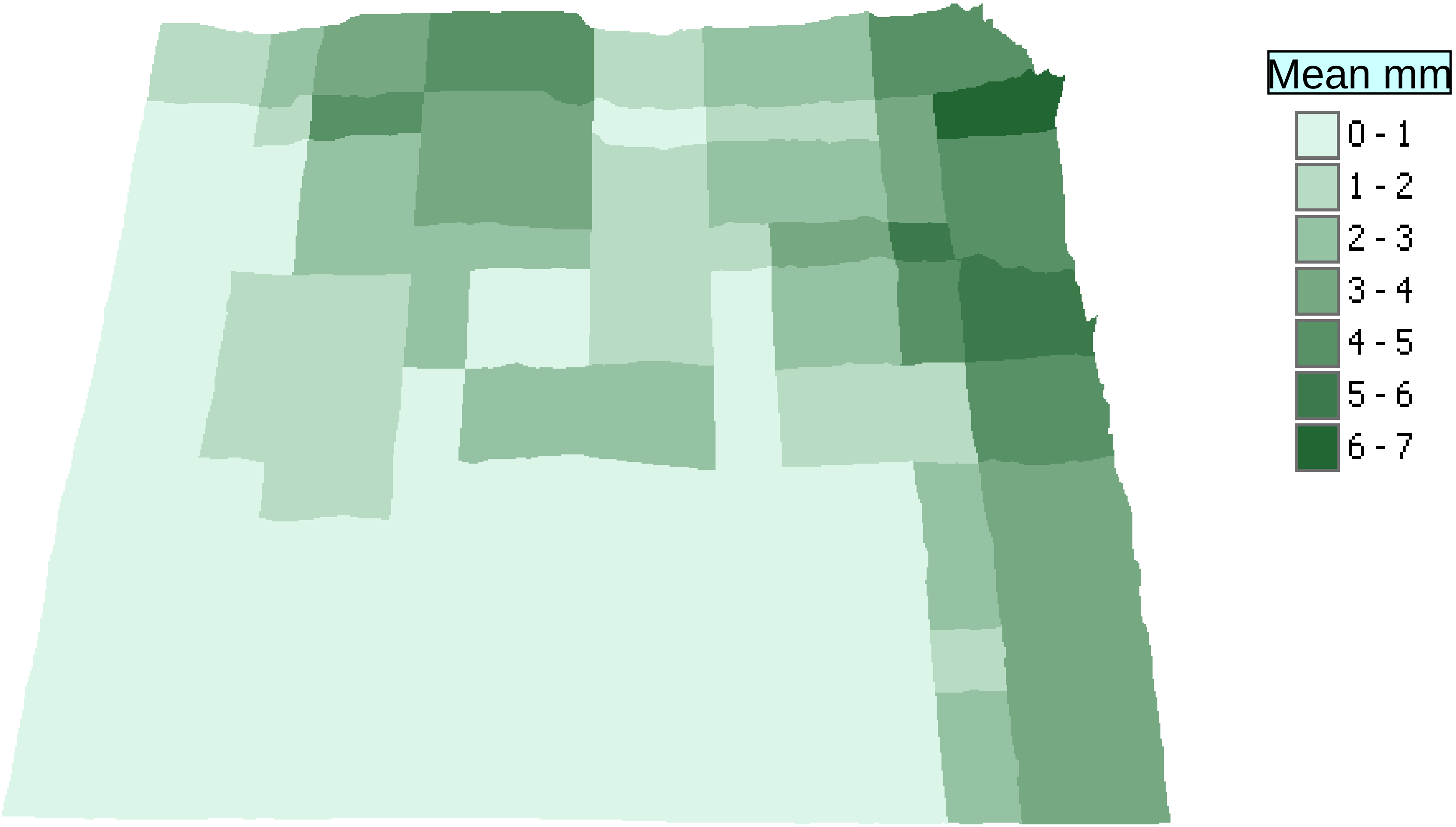
May 01, 1901

Database visualization example: temperature throughout the basin



May 01, 1901

Database and visualization example: 12-day average precipitation



Data: Socio-economic indicators

Economic Indicators for the Nile Basin Countries in 2000

Measure Unit	GDP (Current Billion US$)	GNI (Current Billion US$)	Population Million	Per capita GNI (Current US$)	Agricultural value added % of GDP	Per capita renewable water resource m^3/person/yr
Burundi	0.7	0.8	6.5	120	40.4	1,899
Democratic Republic of Congo	4.3	4.2	50.1	80	50	25,058
Egypt	99.8	97.4	67.3	1,450	16.7	827
Eritrea	0.6	0.6	3.6	180	15.1	1,579
Ethiopia	7.9	8.1	64.3	130	47.4	1,769
Kenya	12.7	13.2	30.7	430	32.4	973
Rwanda	1.8	2	8	250	41.4	1,148
Sudan	12.4	10.3	32.9	310	41.8	1,962
Tanzania	9.1	8.9	33.8	270	45	2,654
Uganda	5.9	6.4	24.3	260	37.3	2,640
Total	117.8	117	227			

Sources: World Bank, World Development Indicators Database, April 2007.

Data: Water Dependency Ratio

Water Resource Indicators for the Nile Basin Countries in 2002								
Measure	Total renewable surface water	Total renewable groundwater	Total renewable water	Water Resources Total water withdrawal for major sectors	Dependency Ratio	Agricultural water use	Domestic water use	Industrial water use
Country / Unit	(10^9 m^3/yr)	(10^9 m^3/yr)	(10^9 m^3/yr)	(10^9 m3/yr)	%	% of total water use	% of total water use	% of total water use
Burundi	12.5	7.5	20	0.29	19.8	82	17	1
Democratic Republic of Congo	1282	421	1703	0.36	29.9	30	52	15
Egypt	56	2.3	58.3	68.3	96.9	31	53	17
Eriteria	6.2	0.5	6.7	0.3	55.6	78	8	14
Ethiopia	120	20	140	5.558	0	96	4	0
Kenya	30.2	3.5	33.7	1.58	32	64	30	6
Rwanda	9.5	7	16.5	0.15	0	39	48	14
Sudan	62.5	7	69.5	37.32	76.9	97	3	1
Tanzania	92.3	30	122.3	5.18	40.9	93	6	1
Uganda	66	29	95	0.3	12.7	39	45	15
Total	1737.2	527.8	2265	119.3				

Sources: include World Bank, FAO, and FAO AQUASTAT database (http://www.fao.org/nr/water/aquastat/water_res/index.stm).

Summary of selected climate impacts from different General Circulation Models (GCMs)

Summary of Selected Climate Impact of General Circulation Models (GCMs)				
	General Circulation Model (GCM)			
	Base	GFDL*	GISSA*	UKMO*
Climate Change				
Change in Average Global Temperature (° C)		4	2.5	5.2
Change in Average Global Precipitation (%)		8	6	15
Water Available for Egypt				
+ Nile Natural Flow (billion of m^3)	84	74	132	130
- Sudan Abstraction (billion of m^3)	18.5	13.6	42.5	41
- Evaporation loss at Aswan (billion of m^3)	10	10.6	11.6	11.9
= Total Available water for Egypt (billion of m^3)	55.5	49.8	77.4	77.6
Total Available Water change from the base (%)		-10.27%	39.46%	39.82%

* Geo-physical Fluid Dynamics Laboratory (GFDL), United Kingdom Meteorological Office (UKMO), and the Goddard Institute of Space Studies (GISSA)

Source: Yates and Strzepek, 1998

Hydrological mass balance

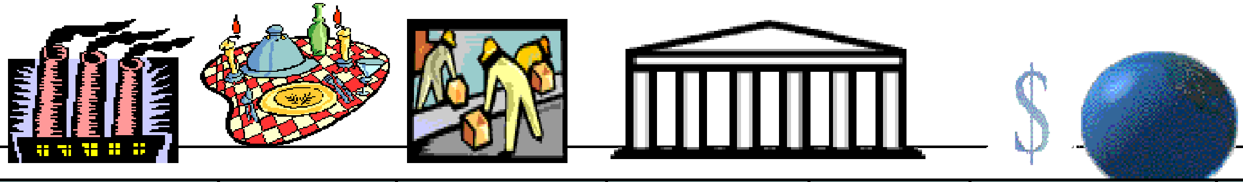
- Delleur (2007) recommended using water budget modeling using the following:

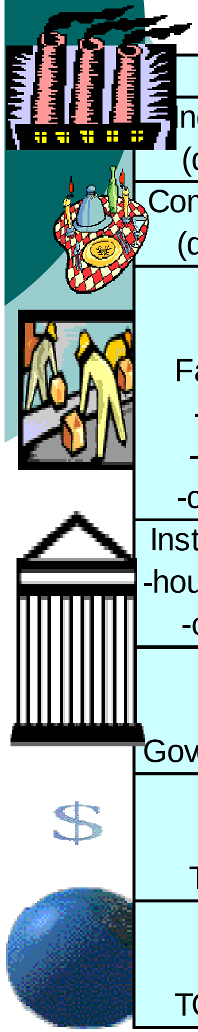
$$R = P - ET \pm O \pm \Delta S$$

- R is the groundwater recharge;
- P is precipitation,
- ET is actual evapotranspiration,
- O is lateral surface runoff, and
- ΔS is the change in water storage in the unsaturated zone.

Delleur, Jaques (Editor). (2007) The handbook of groundwater engineering. Second edition. CRC Press.

Social Accounting Matrix for ECGE





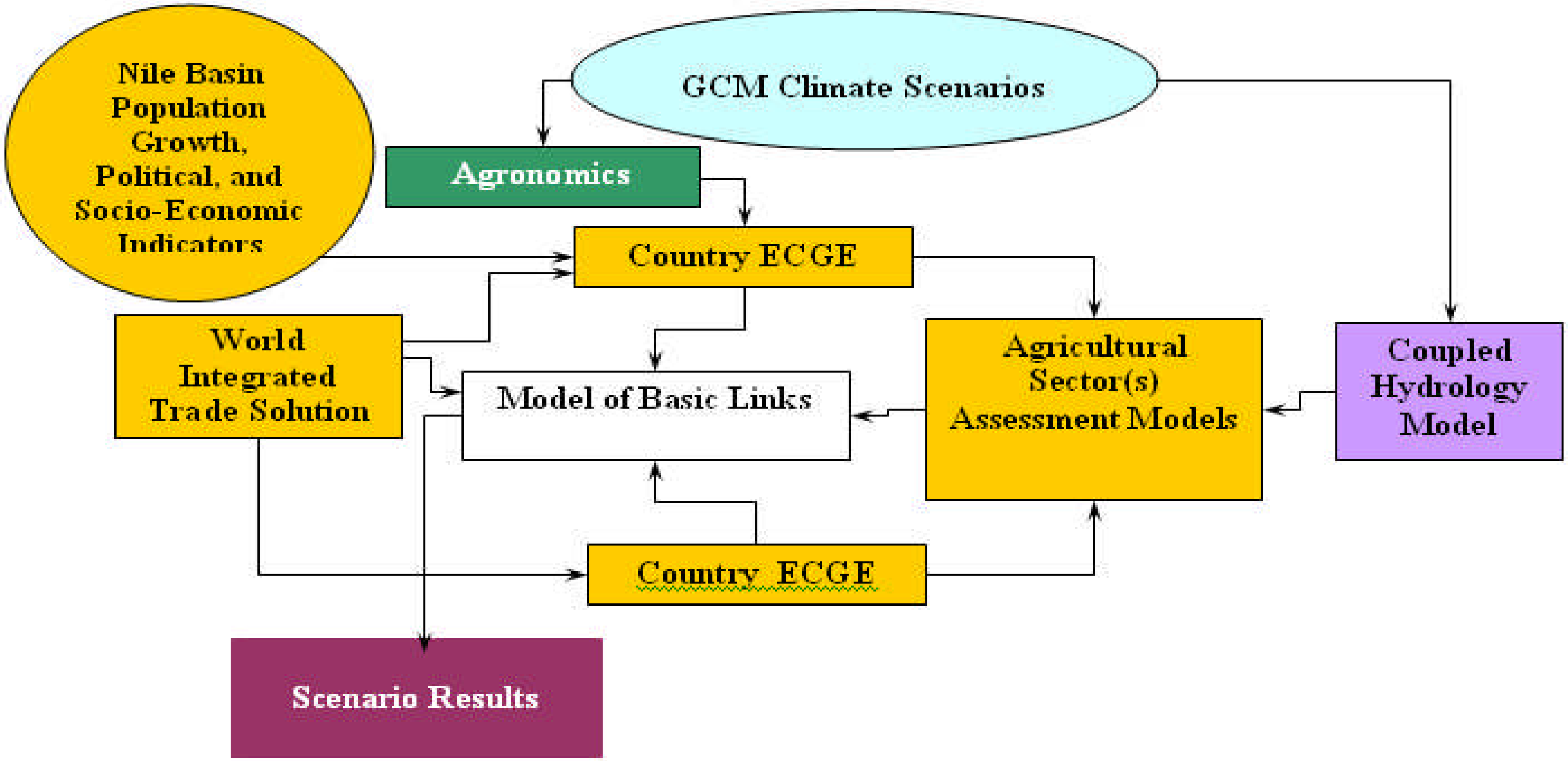
	Industry	Commodity	Factors	Institutions	Govt	Trade	TOTAL
ndustry (detail)		Make					Total Industry Output
Commodity (detail)	Use			Consumption		Exports Output	Total Commodity
Factors -land -labor -capital	Returns to Primary Factors (value added)					Exported Primary Factors (e.g. labor flow)	Total Factor Income
Institutions -households -other	Sales	Sales	Distribution of factor Income		Transfer Payments	Exports	Total Institutional Income
Government	Indirect Business Taxes	Sales Tax	Factor Taxes		Intergover nmental Transfers		Total Government Income
Trade	Imported Purchased Inputs	Imports	Imports			Trans-shipments	Total imports
TOTAL	Total Industry Outlay	Total Commodity Outlay	Total Factor Outlay	Total Institutional Outlay	Total Govt Outlay	Total Exports	

Modified from http://rri.wvu.edu/WebBook/Schreiner/contents.htm

Why use ECGE?

- Dynamic, general equilibrium rather than partial equilibrium
- Tracks many sectors simultaneously
- Generates estimates of producer and consumer surpluses
- Allows for more complexity
- Indigenize inter-country prices spill-over between sectors

Proposed Models Integrations



[a] The World Integrated Trade Solution (WITS) is software developed by the World Bank.

Cimate, hydrology, and economic in computable general equilibrium modeling system (modified from Yates and Strzepek, 1998).

Screening and Multivariate Analysis for Risk and Tradeoff (SMART)

$U\ (x,r)$ is the utility as a function of the random/DM variable x and the set of his risk aversion coefficients r.

The Certainty Equivalent (CE) is measured as the inverse of the utility function

$$CE(x,r) = U^{-1}(x,r)$$

Hardaker et al. (2004 b) defined CE of the negative utility exponential function to be:

$$CE\,(w, r_a(w)) = \ln\left\{\left(\frac{1}{n}\sum_{i}^{n} \exp(-r_a(w)w_i\right)^{-1/r_a(w)}\right\}$$

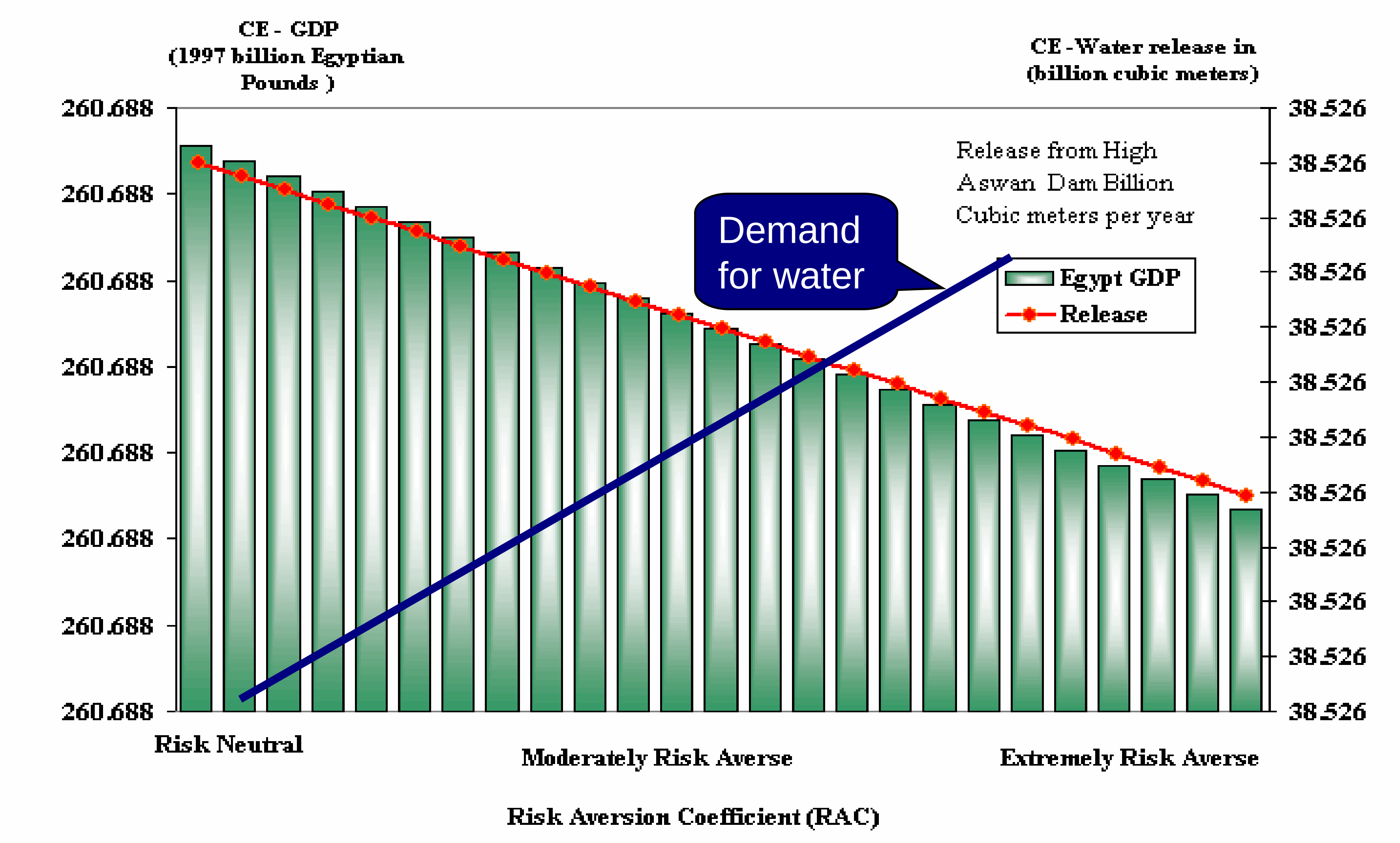
Where

CE is Certainty Equivalent

w is change in wealth or returns (e.g. gross margin); and

r_a is the absolute risk aversion coefficient

Case Study: Tradeoff between economic development and water conservation



Conclusions

- There is strong correlation between economic development and natural resource availability which makes Nile Basin countries very vulnerable to climate change

- Climate, water supply, water demand, and water value databases are needed

- Integrated models uncover new information about climate change impacts

- Water conservation programs may contradict economic development in the short run but not in the long run

- Marketable water, definition of water rights, and water sharing should be highly supported within the Nile basin (Pareto Efficiency applies) for climate change adaptation

- Climate change adaptation strategies (e.g. groundwater projects) complement economic development objectives

Future research

- More tradeoff analysis scenarios, sensitivity analysis, and integrated model validation
- Will Egypt be able to compensate by sponsoring environmental conservation programs upstream the Nile Basin?
- Water may be traded via exchange of final agricultural and energy products…strengthen agricultural and energy trade between Nile basin countries. How much reduction of trade barriers may contribute towards ease of water scarcity?
- How to assign a monetary value for the relationship between economic development and climate change adaptation strategy (e.g. groundwater exploration and use)