

## **Nominated Discussion**

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**The Ability of Integrated Assessment Models to Capture Climate Change Impacts on  
Developing Countries  
The Effect of Sectoral, Temporal, and Spatial Aggregation on Market and Non-Market  
Impacts**

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**Abstract**

Many Integrated Assessment Models divide the world into a small number of highly aggregated regions. Developing countries are aggregated geographically into continental regions or multiple-continental regions, or economically by development level. This paper explores the impact of such aggregation on the accuracy of representing climate change impacts on developing countries. The analysis will focus on water-related impacts, both market and non-market impacts. The paper presents the results of a number of experiments to examine the impacts of spatial, temporal, and sectoral aggregation on the climate change impacts in Africa. A detailed analysis of Egypt is included. The results suggest that these large scale aggregations can not represent the potential non-market climate change impacts, and that market impacts, in many cases, are not accurately modeled.

**Introduction**

Integrated Assessment Models designed for global analysis of climate change issues require, due to their comprehensiveness, the aggregation of global economic, climate, and biophysical systems into a small number of highly aggregated regions. Some models aggregate the globe to a single region, while most divide the world into a number of regions. In these models the developing countries are aggregated geographically into continental regions or multiple-continental regions, or economically by development level (Rotman et al 1996, Hope 1997). These models are very important in providing global and comprehensive perspectives. They attempt to balance the costs of mitigation of climate change with the damages (costs) due to climate change. Therefore, the accurate representation of market and non-market climate change impacts is very important.

Results of global analyses suggest that developing countries will bear higher impact or damages, (Strzepek and Smith 1995, Rosenzweig and Parry 1995, Hope 1997, Mendelsohn et al 1997). Given the importance of North-South and "Burden-sharing" aspects of climate change, it is important that the modeling of impacts on developing countries in Integrated Assessment Models be as accurate as possible. Due to the large spatial aggregation of developing countries, the question of how well Integrated Assessment Models are capturing impacts needs to be addressed.

This paper is to explore the impact of spatial, temporal and sectoral aggregation on the accuracy of climate change impacts on market and non-market aspects of the water resources sector.

## Climate Change Impacts on the Water Resources Sector

Some of the integrated assessment models formally model climate change impacts on parts of the bio-geophysical system. Agricultural yields and "hydrology" are two of the frequently modeled systems. These systems are modeled due to their direct linkage to climate, but also because changes in the systems can easily be converted to monetary values.

Water is a key element in natural, social and economic systems. However, for climate change impact work, the water sector needs to be divided into two parts: Hydrology - the Natural System; and the Water Resources System - the Managed System. In terms of climate change impacts, Tables 1 and 2 below outline the linkage of the two water systems to market and non-market climate change sensitive sectors.

**Table 1 : Hydrology: The Natural System**

- ecosystems
- bio-diversity
- human health
- social disruption

**Table 2 : Water Resources Systems: The Managed System**

- ◆ irrigated agriculture
- ◆ energy – supply, hydropower, thermal cooling
- ◆ industry, commercial, & mining
- ◆ eco-tourism, recreation
- ◆ navigation – transportation
- ◆ health
- ◆ water quality/public health

## From Hydrology to Water Resource Systems

The transformation of hydrology or river runoff into water supply is a very important issue when discussing the availability of water for socio-economic development. The United Nations (1996) estimates that globally there are 45,000 KM<sup>3</sup> of river runoff. However, much of this water comes in flood flows or occurs where there is little potential for storage. It is estimated that about 1/3 of the total river runoff is potential sustainable water supply. Equally important is the fact that the 2/3s remaining is a potential flood hazard.

Civil Engineers have been engaged in major water resource infrastructure projects for thousands of years, to store water and prevent flooding. The ancient civilizations in China, Babylon, Egypt, and Rome were all depended upon water resource development projects.

The development of water resources projects is primarily intended for the redistribution in time and space of the water, by storage in reservoirs and movement via canals. These are major capital intensive projects which require long construction times and have long lives. The major element of water resource development is the Reservoir. While providing a major benefit to society, they have a major environmental impact. Figure 1 and Table 3 are reminders of these facts.

The main intent of this discussion is to point out that just including hydrology in an integrated assessment model is only part of the water resource story. In particular, in modeling adaptation in agriculture via irrigation the transformation from hydrology to water supply is very site specific; causes major environmental impacts; and requires large amounts of capital that in developing countries may be short supply and have impacts on overall economic growth.



Figure 1: The Primary Element of Water Resource Systems  
RESERVOIRS

Table 3: Reservoirs: The Key Water Resources Component

Advantages	
• Reduce Variability	
• Reduce Drought	
• Reduce Floods Impacts	
• Provide Energy	
Disadvantages	
• Major Environmental Impact	
• Major Capital Expenses	
• Location Specific	

## Impact of Spatial Aggregation on Modeling Climate Change Impacts on Hydrology

Many Integrated Assessment Models divide the world into continental regions. This section reports on an experiment to explore the impact of such aggregation on the accuracy of representing climate change impacts on developing countries. Strzepek (1997) performed a detailed analysis of the effects of spatial and temporal aggregation of climate change impacts on the runoff of Africa. This section provides a summary of these results.

Most IAMs aggregated Africa into one Region or two Regions (Northern Africa and Sub-Saharan Africa). What is the impact of such a regionalization on the accuracy of analysis of climate change impacts on the hydrology of Africa? Using a Monthly Water Balance Model (WATBAL, Yates, 1996) thirty-one Major River Basins in Africa were modeled, and climate change impacts for two GCMs were analyzed. The results presented here are for the most detailed (or control case) where GCM results on monthly temperature and precipitation changes were interpolated on a  $0.5^\circ \times 0.5^\circ$  grid. This was compared with two spatial aggregated cases: 1) the mean for all Africa and 2) the mean for Sub-Saharan Africa.

The results are presented for the two GCMs in Table 4 and 5 below. The key findings for the CCCM results are that for the Zambezi Basin the control run suggest that runoff will decrease by -11 percent while using the average for Africa suggests a +15 percent increase. This is a 26 percent difference, but more importantly it is different in sign and of significant magnitude. What then are the market impacts of lost hydropower at Lake Kariba? Positive or negative?

For non-market impacts, what will be the impact on the Sudd Wetlands in Southern Sudan, a valuable ecosystem? +18, as the aggregated analysis would suggest, or -23 as the base case suggests? Similar results are found for the Zambezi Basin and for the Okavango Swamp under the GFDL scenario.

These result show that great care must be taken in estimate impacts on hydrology when continental scale aggregation are being used.

Table 4: Climate Change Impacts on Runoff for Selected African River Basin  
(Results are percentage change from current runoff)

CCCM RESULTS			
Region	$0.5^\circ \times 0.5^\circ$	All Africa	Sub-Sahara Africa
Nile Basin	+63	+23	+11
Zambezi Basin	-11	+15	+18
Sudd Wetlands-Sudan	-23	+18	+3
Okavango Swamp	+9	+8	+6
All of Africa	+6	+17	+15

**Table 4 ctd.: Climate Change Impacts on Runoff for Selected African River Basin**  
(Results are percentage change from current runoff)

**GFDL RESULTS**

<u>Region</u>	<u>0.5 X 0.5</u>	<u>All Africa</u>	<u>Sub-Sahara Africa</u>
<u>Nile Basin</u>	+3	+4	+6
<u>Zambezi Basin</u>	+23	-3	+4
<u>Sudd Wetland-Sudan</u>	+17	+2	+6
<u>Okavango Swamp</u>	-3	+2	+4
<u>All of Africa</u>	+7	+3	+6

**Temporal Aggregation on Hydrology Impacts**

Most developing countries lie in the tropical and semi-tropical regions of the world. In addition, many are found in arid and semi-arid climates. The dominant precipitation patterns in these regions are the monsoon and long wet and dry seasons. This seasonal variation in precipitation has a profound impact on the river runoff with non-linear climate change impacts. Thus using annual analysis of runoff can lead to inaccuracy in modeling climate change impacts. Again, using the WATBAL model with 0.5° X 0.5° representation of climate, an experiment was run to analyze the difference between monthly and annual analysis. This is reported in Table 5 below.

**Table 5: Climate Change Impacts on Runoff for Selected African River Basin** (Results are percentage change from current runoff)

	<u>CCCM</u>		<u>GFDL</u>	
<u>River Basin</u>	<u>Monthly</u>	<u>Annual</u>	<u>Monthly</u>	<u>Annual</u>
<u>Nile</u>	+64	+39	+3	+4
<u>Zambezi</u>	-13	+11	+22	+6

Notice again the change in sign and magnitude of difference for the Nile and Zambezi under CCCM and for the Zambezi in the GFDL.

Hydrologic impacts are very sensitive to temporal and spatial distribution of precipitation, and to some degree temperature. Extreme caution needs to be taken when using

simple continental scale representation of hydrologic impacts to climate change in integrated assessment models.

### Sectoral Aggregation in Economic Models: Lessons From Egypt

Yates and Strzepek (1996) and Strzepek et al (1995) report on integrated impact analyses on Egypt. These analyses looked at the integration of climate change impacts of sea-level rise, agricultural impacts, hydrologic and water resources impacts on the agricultural economic sector and the economy as a whole. The effect of single impact analysis on Egypt, in terms of purely bio-physical indicators and economic indicators, was examined and found to be quite significant. A Computable General Equilibrium Model of Egypt, the Standard National Model of IIASA Basic Linked System, was modified by Yates (1995) and used for this analysis. The following is a summary of these results.

Table 6 presents results for two GCMs. The table shows the biophysical impacts on the land, agriculture, and water on the first row. The World column is the use of world market prices from the Basic Linked System global analyses for each GCM. The second row shows the impact on the Egyptian economy (percentage change in GDP/capita from the 2060 base case) for changes in each sector with the integration of all sectoral impacts in the final row. The final row is the impact of climate change on Egyptian Food self-sufficiency. This is a very important policy indicator for many developing countries.

**Table 6: Impacts of Including Climate Change Impact Sectors on the Economy-Wide Impacts on Egypt (The results are percentage change from a 2060 Base run with current climate)**

**GFDL**

<b>Impact</b>	<b>Land</b>	<b>Yield</b>	<b>Water</b>	<b>World</b>	<b>Integrated</b>
<b>Physical</b>	-4	-19	-12	--	--
<b>GDP</b>	-1.5	-4.1	-3.1	+0.8	-1.6
<b>FSS</b>	-5.6	-8.9	-12.2	8.1	-22.2

**GISS**

<b>Impact</b>	<b>Land</b>	<b>Yield</b>	<b>Water</b>	<b>World</b>	<b>Integrated</b>
<b>Physical</b>	-4	-12	+30	--	--
<b>GDP</b>	-1.5	-3.0	+4.5	+1.3	+4.7
<b>FSS</b>	-5.6	-7.5	+23.7	-6.6	-7.8

There are two important results to be highlighted here. First, the results show that economy-wide impacts measured by GDP are much less than the direct biophysical impacts. Note that for the GFDL scenario, there is an average 19 percent decrease in agricultural yields in Egypt and a 12 percent decrease in water supply. This translates into only 4.1 and 3.1 decrease in GDP respectively. Note, that for the GISS scenario there is a 30% increase in water supply but only a corresponding 4.5 percent increase in GDP.

The second major insight is that the world market prices have a major impact on the GDP change for Egypt. In the GFDL scenario, with sectoral impacts on GDP of decreases on the order of 3 to 4 percent, the integrated impact is only a decrease of 1.6 percent. This mitigation of sectoral impact is attributable to changes in world market prices. The same is seen for the GISS results.

## **Conclusion**

The results presented above show that aggregation in integrated assessment models must be taken with care to properly model the climate change impacts on developing countries. This is based on two factors, 1) the importance of agriculture and water resources in developing country economies, and 2) the sensitive non-market potential impacts in many developing countries, especially wetlands.

Listed below are some of the key insight from this synthetic analysis of previous modeling results.

### **Insights for IAM of Developing Countries**

- ◆ Key Factors
  - ◆ World Markets
  - ◆ Trade Policy
  - ◆ Food self-sufficiency
  - ◆ Non-Market not captured at large aggregation
  - ◆ Many national models need sub-national scale for both market and non- market : China/India/Russia/Brazil



## References

- Hope, C. 1997, *Developing Country Impacts in Integrated Assessment Models of Climate Change*, IPCC Workshop on Intergrated Assessment Model, Tokyo, March 1997
- Mendelsohn, R., W. Morrison, M. Schlesinger, and N. Andronova, 1997, *Country-Specific Market Impacts of Climate Change*, IPCC Workshop on Intergrated Assessment Model, Tokyo, March 1997
- Rotmans, J, H. Dowlatabadi, & T. Parson, 1996 , *Integrated Assessment of Climate Change: Evaluation of models and other Methods*
- Rosenzweig, C . and M. Parry, 1995, World Agriculture, in Strzepek, K.M. and J.B. Smith, editors. 1995, *As Climate Changes: International Impacts and Implications*, Cambridge University Press, Cambridge
- Strzepek, K.M., 1997 , *Impact of Spatial and Temporal Aggregation on Climate Change Impacts on the River Runoff of Africa*, In Press
- Strzepek, K.M. S.C. Onyeji, M. Saleh, and D.N. Yates, 1995, An Integrated Assessment of Climate Change Impacts on Egypt. In Strzepek, K.M. and J.B. Smith, editors. 1995, *As Climate Changes: International Impacts and Implications*, Cambridge University Press, Cambridge
- Strzepek, K.M. and J.B. Smith, editors. 1995, *As Climate Changes: International Impacts and Implications*, Cambridge University Press, Cambridge
- United Nations, 1996, *Comprehensive Freshwater Assessment*, In Press
- Yates, D.N., 1995, *A Systematic approach to climate change impact Assessment: Integrating water resources into a consistent economic framework*, unpublished Ph.D. dissertation, University of Colorado
- Yates, D.N. 1996, "WATBAL, Water Balance Model for Climate Change Impacts," *International Journal of Water Resources Development*, 12 June 1996
- Yates, D.N. & K.M. Strzepek, (1996), Modeling economy-wide climate change impacts on Egypt: A case for an integrated approach, *Environmental Modeling and Assessment* (1), November 1996