IWMI / ICID Scenario Development Orientation Workshop for India & China

Proceedings of the Workshop Held in Moscow, Russia, September 3rd and 4th, 2004

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Introduction

The Country Policy Support Program (CPSP) of the International Commission of Irrigation and Drainage (ICID) contributes developing effective options for water management to achieve acceptable level of food security and sustainable development in developing countries, especially in India and China.

As part of the CPSP studies, International Water Management Institute (IWMI) and International Food Policy Research Institute (IFPRI) are to upgrade the IWMI'S PODIUM and IFPRI's IMPACT-WATER models to address country specific issues for wider use by the policy makers and researchers and also to increase the interaction between the two models. PODIUM, the Policy Dialogue Model, developed by the IWMI in 1999, as part of the World Water Vision exercise, was extensively used by researchers and policy makers in developing country vision scenarios. The upgraded PODIUM model, called PODIUMSIM is adapted for two countries India and China. The PODIUMSIM model for India and China facilitates generating future water supply and demand scenarios at river basin level for India and China. The interaction between PODIUM and IMPACT-WATER is increased through the new global model WATERSIM.

The Scenario Development Orientation Workshop, held on 3th and 4th of September in Moscow, Russia, is part of the IWMI/IFPRI component of CPSP studies. The overall purpose of the workshop is to bring policymakers and researchers of India and China to provide information and generate future scenarios of water supply and demand for the two countries. The information generated by PODIUMSIM facilitates the discussion around key issues of water supply and demand.

This report first gives an overview of the proceedings of the workshop and then gives the background papers, presentations and the summary presentations of the group discussions for India and China.

Overview of Workshop Proceedings

The Leader, Comprehensive Assessment Program, Dr. David Molden welcomed the participants on behalf of IWMI. He appreciated their enthusiasm to participate in the workshop and expressed the desire to have fruitful dialogue among specialist of various disciplines gathered for the workshop. The secretary general Mr. S. Gopalakrishnan, welcomed the participants on behalf of ICID and mentioned that this workshop is the last among the several dialogue workshops under the CPSP studies in its phase I. Mr. Gopalakrishnan also emphasized the value of these workshop for exchanging ideas between researchers and policy makers in various disciplines in assessing future water needs of different sectors, value of their inputs to the CPSP studies, and ICID's commitment to hold similar dialogues in future activities, possibly in CPSP phase II.

Increased interaction of various disciplines is also the main message of the ICID president Hon. Bin Abdul Keizural's key note address. Hon. Mr. Keizural emphasized the importance of dialogue to increase communications between different stakeholders of water use. These workshops would be ideal forums for policy makers and researchers of various disciplines to exchange ideas, increase knowledge and appreciate knowledge of other disciplines that would lead to generating realistic water supply and demand scenarios for different sectors, especially for the people, agriculture and environment.

Application of CPSP hydrological model in river basin studies in India and China and implications of findings at national level were presented in the first day morning session. Rest of the workshop devoted time for discussions of scenario development and of the key drivers of the PODIUMSIm model.

River Basin Studies of India

The national commissions of irrigation and drainage of India (INCID) presented the findings of river basin studies in India. The studies include water surplus Brahmani river basin in the north-east and in water deficit Sabramati river basin in the north-west of India. The CPSP hydrologic model, used in river basin studies in both India and China, was developed to assess how evaporation management through various land use process can be used as a potential management intervention to increase or decrease the river flow or aquifer recharge.

Brahmani river basin: Application of CPSP model shows Brahmani river basin would not be water short even with increase agricultural and industrial water use scenarios. The study shows that the nature is by far the largest consumptive water use sector, there is a risk of water logging in the future, further storage development is required for meeting additional withdrawal requirements and watershed management for increasing productivity in the rainfed agriculture.
Sabramati river basin: The studies in the Sabramati river basin show potential strategies for water management are to use water harvesting and soil and water management to reduce non-beneficial Evapo-transpiration (ET) in the nature and agriculture sector which exceeds annual river flow. The study also shows unsustainable ground water use at present and increase risk of water pollution. The water diversions from the Narmada river basin would reduce unsustainable water use to some extent and are necessary for meeting future water withdrawals including improving low flows.
Extrapolation to other river basins of India: The extrapolations of these studies show similarities of inference of surface water issues of Sabramati basin to the issues in the Pennar, Cauvery, Indus, Ganga, Subarnarekha, Mahanadi and Tapi river basins and groundwater issues of Sabramati basin to the issues of Indus, Ganga, Subarnarekha, Krishna, Pennar and Cauvery. The implications of issues arising at Brahmaputra and Godavari river basins have are similar to those due to high flows and low groundwater use in the Brahmani river basin.

River Basin Studies of China

The national commissions of irrigation and drainage of China (CNCID) presented the findings of river basin studies in China, which included Jiaodong peninsular basin in the south-east and Quintang river basin in the north-east in China.
Jiaodang river basin: Study shows that consumptive use of the nature sector would increase with expanding forest area, non-beneficial ET in agriculture would decrease. Compared with the increase in command area, the beneficial ET in the basin would considerably increase with better water management. The groundwater use is high at present and should be moderately exploited in the future. Increasing return flows would risk water pollution and preventive measures are required.

Quintang river basin: Almost all water withdrawals and thus beneficial consumption of this basin at present are from surface water. There is a huge potential for increasing groundwater withdrawals.

Interpolation to other river basin in China: China is a vast country and water supply and demand vary substantially in large river basins. However, similarities with respect to ratio of water withdrawals to runoff in both surface and groundwater do exist respectively between Jiaodong and Songliao, Yellow river, Huaihe and Haihe river basins and Quingtang and Yangtze, Pearl, Southwest and Southeast river basins.

Scenario Development

The major objective of this part of the workshop was to explore plausible futures of water supply and demand and assess their implications for policies. Two groups of Indian participants and one group of Chinese participants first develop a story line of plausible scenarios and then analyzed quantitatively and qualitatively the implications of the developed story line and their assumptions. One scenario prioritized water for food and people and the other prioritized water for people and nature.

Water for food and people (group1-India): This group built the story in line of "Storage for food and water security". Group noted several recent trends including the plateau in net irrigated area, contribution of irrigation to increasing cropping intensity, problems in classification of rainfed lands, globalization of world economy. Group also noted that elimination of labor migration barriers would result in virtual water trade or the presence of labor migration barriers would result in national self sufficiency targets for food production. The main paths to rural poverty alleviation in the future are through increasing urbanization and generating employment in the services sectors and also providing more irrigation to agriculture. The quantification of the main drivers are given in table 1.

Table 1. Scenario drivers for Water for food and people group

	Present condition			Desired future (in 2025)		
Drivers	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total
Net cultivated area (Mha)	60	80	140	80	60	140
Gross cultivated area (M ha)						
1st season (Rabi+hot weather)	35	30	65	50	20	70
2nd season (Kharif)	60	70	130	80	80	160
Total	95	100	195	130	100	230
Grain production						
Area (M Ha)	95	100	195	130	80	210
Yield (ton/ha)	1.5	0.7		2.5	1.3	
Production (M ton)	142.5	70	212.5	325	104	429

Water for people and nature (group 2- India): This group developed story lines for three scenarios and the drivers (mainly qualitative) are given as:

Scenario 1 will be to

- find best ways to use water in local area
- respect historical rights of water use, implying that large storage dams may be some what reduced (like in Mekong)
- design systems based on needs
- apply similar considerations for our regional countries (as Prime Minister of India mentioned in the last SARC summit)

- pass experiences of reform process to other SARC and
- give priority to ground water development, water harvesting, watershed development and local ponds as they are suitable and needed.

Scenario 2 includes

- designing river basin plans with increase in storage- leading to conjunctive use
- developing operational strategies for local level water management institutions, community collateral for financing, news organisation designs.
- assessing the technology potential in highly stressed regions and looked into very seriously in achieving them and

These are compatible with WTO guidelines as at Geneva, but if progress is slow developing alternative scenario's.

Scenario 3 includes

- developing scenarios with population stabilisation year around 2050,
- appropriating rights, for both existing and new storages, are not based on water but based on function (land-) and water saving should lead to greater equity.
- developing a policy on conjunctive use (watershed, upstream, storages),
- improving existing canal systems.
- releasing 7-10 percents of gross storage in the non-monsoon period as minimum river water flow,
- progressive water rates based on volumetric releases,
- measuring storage in October and sharing the deficit/ surplus by all riparian water rights holders and
- shifting the investment allocations to 40 to 30 to 30 between large storage, watershed and ground water development.

China Group. This group mainly built the story line keeping a balance approach to water for food and environment. Group noted following important trends.

- Population is still increasing though growth rate is decreasing
- Present agriculture share is 70 percent of the water withdrawals (about 550km3) but there is an increasing share from the domestic and industrial sectors,
- Irrigated farm land produces about 75 percent of the grain production and 95 percent of the cash crops,
- Increasing demand for water for people due to urbanization
- Ecological degradation, drying up of rivers, peoples desire for better environment for leisure activities thus requirement of more water for nature sector

Group noted that future scenarios need to consider

- The level of water use efficiency increase in irrigation under different national self sufficiency targets
- Same level of water withdrawals for irrigation in the future
- WTO guidelines and international trade
- The water availability under basin water transfer projects from south to north.

Key Drivers of PODIUMSIM

Group provided constructive comments on the key drivers of the PODIUMSIM models. The default scenario of the models at present describes the Business as Usual scenarios (BAU) of the water vision exercise. The group noted that for effective use by the policy makers and researchers in respective countries, the model has to use the planning commission scenario drivers in the place of present default scenario drivers. This is especially true in the PODIUMSim India model, as several modeling groups have developed scenarios separately for different component of the PODIUMSIM model such as consumption, production, water supply and demand. Integrating them into the PODIUMSIm model would help especially to look into the issues related to integrated water resources management of river basins. Participant's emphasized the fact that the model can be used to do a sensitivity analysis of the national projections with respect to the changes in the drivers of the model.

Conclusion

All participants appreciated the methodology of the CPSP hydrologic model and were of the view that an improved version of the model would be a good tool to assess the consumptive water use by the different land phases within the basins. Because there are wide variations of water supply and demand in large basins, the extrapolation of findings from the two small basins to large basin may not be accurate.

The PODIUMSIM model needs to be modified to include the scenarios developed by the planning commission as its default scenario. These would help, especially the policy makers and researchers of the respective countries to assess the sensitivity of different drivers on the planning commission projections.

The general consensus of the scenario development discussion was that the environmental water need assessment including minimum river flow requirements need to be further developed and be included in any water use assessment in a river basin.

The potential for groundwater development, water harvesting and their effects on basin hydrology needs to assessed. These will be valuable information future water resources development plans.

Annex A. Agenda

IWMI / ICID Scenario Development Orientation Workshop for India & China
September 3rd and 4th 2004, Moscow, Russia

Background

The goal of the "Country Policy Support Programme (CPSP)" of the ICID is to contribute to develop effective options for water management to achieve an acceptable food security level and sustainable rural development while integrating needs of the three sectors, through assessments made primarily in India and China. The CPSP outputs will be available for the Dialogue on Water, Food and Environment which aims at bridging the gap between food and environmental sectors through open and transparent dialogue after generating necessary knowledge base where necessary.

The IWMI and IFPRI component of the CPSP is to improve and upgrade the PODIUM and integrate it with IMPACT-Water[1] model for wider use by policy makers and researchers in developing countries. The improved models will help assess future food and water needs and support the preparation of National Water Policy interventions for India and China. The improved version of the PODIUM model, PODIUMSim has been applied for India and China at the country level, and in two detailed basin studies in each country. PodiumSIM allows for the development of alternative scenarios by changing such variables as irrigated and rainfed area and yield, levels of national food self sufficiency and trade, and population and nutrition levels, and environmental flow requirements. As such, the model is ideal for achieving objectives of CPSP and lead to facilitate Dialogue on Water, Food and Environment.

The overall purpose of the orientation workshop, in line with CPSP objectives is to provide information and generate ideas in support of country policy development. It will bring together people of scientific perspectives to jointly explore different scenarios of future water use. PodiumSIM will be used as a tool to stimulate discussion around key issues. The workshop aims to bring better understanding of various points of view; to build bridges between proponents of various viewpoints; and to hopefully spark new thinking on improved future water management.

Workshop Objectives

- To share the results of CPSP basin studies and PodiumSIM applications of India and China and on their contribution in generating primarily consumptive water allocation sceneries in the two countries for the three sectors food, people and nature
- To improve understanding of issues of water, food and environment by generating alternative scenarios and considering their implications for food security and environmental sustainability.
- To provide feedback to future model development.

Process

To achieve the objectives, a two days workshop is proposed on 3rd and 4th of September 2004 in **Moscow, Russia**. The participants of the workshop are expected to discuss the important issues and drivers of future water supply and demand scenarios for the two countries and the food security, and environmental sustainability implications that would arise from different scenarios. A workshop report will be prepared that highlights key points and issues discussed during the event, and plans for future action.

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[1] IWMI and IFPRI are joining efforts to produce WaterSIM under the Comprehensive Assessment of Water Management in Agriculture. PodiumSIM, developed as part of the WaterSIM package, is ready for both India and China.

IWMI / ICID Workshop, September 3- 4 2004 – Moscow, Russia

Day 1 – September 03, 2004

08:15-08:45	Registration
08:45-09:00	Welcome speech by the Secretary General ICID
09:00-09:15	Key note speech by the President ICID
09.15-09.30	CPSP basin assessment model – an introduction
09.30-10.45	CPSP basin assessments for selected basins in India and China
10.45-11:15	Tea/Coffee
11.15-12.00	CPSP basin assessments for selected basins in India and China (contd..)
12.00-12.45	CPSP basin assessment results – policy interventions as also EFR and other improvements needed
12.45-13:45	Lunch
13:45-14:15	PODIUMSIM/Key issues for scenario development Diet, Population, Irrigated and Rain-fed agriculture, water transfers, Needs for domestic/industrial purposes, water consumed by ecosystems needs and Trade
14.15-14:45	Introduction to the working groups (what should be done in the next 2 days. How it should be done? Explanation of four working groups and rationale for grouping participants into groups)
14.45-16:00	Scenario Development (4 working groups– 2 from India and 2 from China). The two working groups from each country work on two different themes. Group 1 and 3 Water for Food: Meeting national food demand through efficient water utilisation and further development- Issues and Impacts on consumptive water sharing between Food, People & Nature Sector Group 2 and 4 Water for People & Nature: Meeting requirements in the basins- for terrestrial & aquatic eco-systems, degradation due to domestic and industrial waste-waters
16:00-16:15	Tea/Coffee
16:15-17:15	Interactive session with PODIUMSim
17:15-17:45	Wrap up of the discussions within the groups and finalisation of group outcomes for “Report Back” session the next day. Group facilitator to prepare the finding/outcome notes.
17.45	Group dinner

Day 2 – September 4, 2004

09:00-09:10	De-briefing on day 1
9.10-10:30	Report back sessions focusing on-. • Scenarios • Processes on scenario development • Issues identified in the process • Implications on food security and environmental sustainability Group 1: Water for Food & People (Indian scenario) Group 2: Water for Nature (Indian scenario) Group 3: Water for Food & People – (China scenario) Group 4: Water for Nature – (China scenario)
10.30-11:15	Discussion on water for food, people and nature- generated scenarios
11:15-11:45	Tea/Coffee
11.45-13:15	Water for food, people and nature Scenarios (India and China groups)
13:15-14:15	Lunch
14:15-15:15	Reporting Back session on the group discussions of China and India
15:15-15:45	Tea/Coffee
15:45-16:15	Introduction to framework of WATERSIM
16:15-17:00	Discussion on WATERSIM
17:00-17:30	Summary of key issues and sum-up plenary and recommendations
17.30	Free evening

Annex C. Workshop Participants

No	Name	Phone/Fax	Email	Address
1.	Hon. Bin Abdul Keizrual			
2.	Mr. S. Gopalakishnen	91-11-26116837/ 91-11-26115962	icid@icid.org	48 Nyaya Marg, Chanakyapuri, New Delhi 110021, India
3.	Dr. S.A.Kulkarni	91-11-26116837	icid@icid.org	
4.	Mr. A.K. Sinha	91-11-26101057	Nwp_cwc@redippmail.com	Central Water Commission, 840 (S), Sewa Bhawan, R.K. Puram, New Delhi 110 066 India
5.	Dr.B.P.Das	91-674-2547364	bishnupdas@hotmail.com	717, Sahid Nagar, Bhubaneswar 751 007, Orissa
6.	Mr.A.D.Mohile	91-11-26535235/ 91-9891154061	anildmohile@yahoo.com	D-6, DDA MIG Flats, Saket, New Delhi 110017
7.	Mr. L.N.Guptha	91-11-26960452/ 91-9891134061	lngupta@yahoo.co.uk	12-D, Vijay Mandal Enclave, Near IIT Gate, New Delhi 110 016
8.	Dr. Biksham Gujja	91-40-23296161	b.gujja@cgiar.org	
9.	Prof. Yoginder K. Alagh	91-79-26859950/ 91-79-26855984	alagh@icenet.co.in	45 Surdhara, Near Doordarshan, Thaltej, Ahmedabad 380054, India
10.	Dr. Vijay Pranjpey	91-20-25671448	paranjpye@yahoo.co.uk	Gomukh Trust , 'Durga', 92/2, Gangote Path , Opp. Kamla Nehru Park , Erandawane, Pune 411 004 , India
11.	Dr. Malavika Chauhan		malavikachauhan@hotmail.com	School of Environmental Sciences, Jawaharlal Nehru University, New Delhi 110067 India
12.	Dr. Kamta Prasad	91-11-22377199/ 91-11-22379669	irmed@vsnl.com	
13.	Dr. V.M. Ranade	91-20-24336076	Vranade2003@yahoo.com	A-1/1, Rambag Colony, `Parijat', Navi Peth, Pune 411 030, Maharashtra
13.	Dr. Gao Zhanyi	86-10-68423313/ 86-10-68451169	gaozhy@iwhr.com	China Institute of Water Resources &Hydro-power Research , N0.20 West Chegongzhuang Rd., Beijing 100044, China
14.	Ms. Wang Shaoli	86-10-68415522-6500	shaoliw@iwhr.com	
15	Ms. Mu Jianxin	86-10-68457179/ 86-10-68451169	gaozhy@iwhr.com	
16.	Mr. Yin Changbin	86-10-68919633/ 86-10-68775415	yinchanb@mail.iaas.net.cn	Institute of Planning, Design and Research, Yellow River Conservation Commission, Zhengzhou, Henan Province, P.R. China
17.	Mr. Li Jingzong	86-371-6023779/ 86-371-6022444	Lljjzz58@yahoo.com.cn jzli@yellowriver.gov.cn	
18.	Ms. Qin Liyi	86-10-85322699/ 86-10-85322693	qinliyi@iucnt.org	
19.	Dr. David Molden	94-11-2787404/ 94-11-2786854	d.molden@cgiar.org	127 Sunil Mawatha, Pelawatta Via Battaramulla, Sri Lanka
20.	Dr. Madar Samad	94-11-2787404	m.samd@cgiar.org	
21.	Dr. Upali Amarasinghe	94-11-2787404	u.amarasinghe@cgiar.org	
22.	Mr. Ian Makin	66-1-8462471/ 66-2-5611230	i.makin@cgiar.org	PO Box 1025, Kasetsart University, Bangkok 10903, Thailand
23	Mr. Mohd Azhari bin Ghazalli		azhari@water.gov.my	Irrigation and Agricultural Drainage Division, Ministry of Agriculture and Agro-Based Industry, Jalan Sultan Salahuddin, 50626 Kuala Lumpur, Malaysia.

Annex D. Background papers

IWMI / ICID Scenario Development Orientation Workshop for India & China : Background paper

Upali A. Amarasinghe

The IWMI/IFPRI component of the ICID's Country Policy Support Program improve and upgrade the Policy Dialogue Model, PODIUM and integrate it with IMPACT-Water model for wider use by policy makers and researchers in developing countries. The upgraded PODIUM models, now called PODIUMSIM are available for the two countries India and China. The PODIUMSIM allows for development of alternative scenarios of food and water supply and demand. The model generates scenarios according to changes in key factors, called drivers, including population and nutritional requirement, irrigated and rainfed area and yield of different crops, food self sufficiency and trade, water requirements of irrigation, domestic, industrial and environmental sectors. The PODIUMSIM model is an interactive tool in simulating discussion around key issues of water for food, people and nature.

The primary objectives of the IWMI/ICID workshop are

1. to share the results of detailed studies of two basins in India and China by the INCID and CNCID and
2. to develop alternative scenarios of water for food, people and nature for India and China using PODIUMSIM as a supporting tool.

The scenario development in objective 2 includes

1. investigating options for meeting water for people and water for national food demand through better utilization and new development and their implications on environmental sustainability
2. investigating options for meeting water for people and water for nature and their implications for meeting national food security and
3. investigating options for meeting water demand for people, food and environment and their implications on food security and environmental sustainability.

Default Scenario in PODIUMSIM

To assist developing alternative scenarios, PODIUMSIM provides default scenarios for river basins of India and China. The default scenarios are mainly based on the assumptions of the Global Water Vision Business as Usual (BAU) scenario (Rijsberman 2000) and also on the assumptions of IWMI base scenario (IWMI 2000) and the country panning commission reports (GOI 2000,). Changes to drivers of default scenario generate different options under alternative scenarios. The projections and the growth rates of the key drivers under default scenarios are provided here. The detailed information of river basins for India and China is available in the PODIUMSIM India and PODIUMSIM China models.

Key drivers of PODIUMSIM model

The PODIUMSIM model has four main components estimating crop consumption, crop production, water demand and water supply.

Crop requirement estimation module has following key drivers.

1. Urban and Rural population growth
2. Growth of total calorie supply per person
    - 2.1 Growth of calorie supply from grain (including rice, wheat, maize, other cereals, Pulses for India and including roots and tubers for China.
    - 2.2 Growth of calorie supply from oil crops
    - 2.3 Growth of Calorie supply from fruits and vegetables
    - 2.4 Calorie supply from animal products
3. Per capita food consumption of rice, wheat, maize, other cereals, pulses, oil crops (equivalent), vegetables,
4. Conversion ratios of feed to calorie supply from animal products(kg of feed per 1000 calories)
5. Seeds+Waste+other use as a percent of total consumption

Annex tables 1a and 1b show the total grain requirement of different basins under the default scenario in India and China.

The domestic grain consumption (rice, wheat, maize, other cereals and pulses) in India under the default scenario is projected to increase from 187 M MT in 1995 to 284 M MT by 2025. In per capita terms it increases from 552 grams per day to 586 grams per day. The food consumption is projected to increase slightly from 490 grams/day per person in 1995 to 509 grams/day per person in 2025.

The domestic grain consumption (rice, wheat, maize, other cereals, pulses, dry equivalent roots and tubers) in China is projected to increase from 403 M MT in 2000 to 532 M MT by 2025. Per capita domestic requirement is projected to increase from 862 grams/day to 1015 grams/day. Of this per capita food consumption is projected to decrease from 549 grams/day to 500 grams/day.

Crop production estimation module has following key drivers.

1. Net crop area
2. Gross crop area
3. Net irrigated area
4. Gross irrigated area
5. Irrigated and rainfed area of rice, wheat, maize, other cereals, pulses, oil crops, vegetables, roots and tubers, sugar, fruits and cotton and
6. Irrigated and rainfed yield of rice, wheat, maize, other cereals, pulses, oil crops, vegetables, roots and tubers, sugar, fruits and cotton.

Annex tables 2 (a & b), 3 (a & b) and 4 (a & b) give the irrigated and rainfed grain crop area, yield and production of different basins in India and China.

The grain production in India is projected to increase from 187 M Mt in 1995 to 255 M MT in 2025. In 1995, the grain area was 65 percent of the gross sown area. This is projected to decrease to 62 percent by 2025. Irrigated grain area is projected to increase from 39 percent of the total crop area in 1995 to 50 percent of the grain area in 2025. The contribution irrigated area to total grain production is projected to increase from 61 percent in 1995 to 74 percent in 2025.

In China, the total grain area is projected to decrease from 561 percent to 58 percent over the period from 1995 to 2025. The irrigated grain area and production is projected to increase from 56 and 64 percents in 1995 to 59 and 71 percents respectively.

Crop Production surplus/deficits

The production of different crops, individually and also as aggregates for grains and non-grain crops are compared with crop requirements. The crop production surplus or deficit, the difference between crop production and requirement as percent of crop requirements shows the extent of trade required to meet domestic consumption requirement.

Table 1 (a & b) show crop production surplus or deficit as a percent of total crop requirements of different river basins in India and China.

Under the default scenario both countries are projected to record substantial grain production deficits. In India, small grain production surplus (0.1% of the consumption) in 1995 is projected to change to 8 percent production deficits in 2025. In China production deficits is projected to increase from 1.2 percent of crop requirements to 7.3 percent of the domestic requirement.

Table 1a. Grain crop production surplus/deficits - % of total requirement of Indian River basins

	Crop production surplus/deficit - % of total requirement					
	1995			**2025 Default scenario**		
River Basins	**Grain crops**	**Non-grain crops**	**Total crops**	**Grain crops**	**Non-grain crops**	**Total crops**
	%	**%**	**%**	**%**	**%**	**%**
Indus	226	-18	66	190	-51	13
Ganga	-17	-11	-13	-28	-33	-32
Bramhaputra	14	11	12	7	-23	-15
Barak & Others	-41	37	10	-49	-5	-17
Subernarekha	5	26	19	-7	-9	-8
Brahmani-Baitarni	15	87	62	6	41	32
Mahanadi	57	110	92	44	131	108
Godavari	-6	-9	-8	-6	-27	-22
Krishna	-14	-8	-10	-16	-21	-20
Pennar	19	-6	3	9	-21	-13
Cauvery	-19	-1	-7	-21	-9	-12
Tapi	-37	-24	-28	-53	-38	-42
Narmada	36	-42	-15	24	-54	-33
Mahi	-14	-33	-26	-31	-47	-42
Sabarmati	-45	-15	-25	-52	-44	-46
West flowing rivers 1	-32	-29	-30	-46	-58	-55
West flowing rivers 2	-56	40	7	-54	27	5
East flowing rivers 1	35	56	48	42	36	38
East flowing rivers 2	-10	-6	-8	-6	-16	-13
India	0.1	-1.2	-0.7	-9	-22	-19

Table 1b. Grain crop production surplus/deficits - % of total requirement of Chinese river basins

River Basins	Crop production surplus/deficit - % of total requirement					
	2000			2025 Default scenario		
	Grain crops	Non-grain crops	Total crops	Grain crops	Non-grain crops	Total crops
	%	%	%	%	%	%
Songliaohe	52	-43	-27	38	-35	-21
Haihe	-5	39	32	-10	39	30
Huaihe	19	23	23	11	15	14
Yellow river	23	-16	-9	9	-18	-13
Yangtze river	-7	-13	-12	-15	-14	-14
Pearl river	-41	7	-1	-46	5	-5
Southeast	-41	-12	-17	-46	4	-5
Southwest	-3	3	2	-17	6	1
Inland	46	59	57	45	45	45
China	0.9	-0.7	-0.5	-7.3	-1.6	-2.6

Water requirement module's four components estimate water requirements for agriculture, domestic, industry and environment. Following are the key drivers estimating water requirements of different sectors.

Agriculture water requirements:

1. Irrigated area of different crops
2. Groundwater irrigated area
3. Field scale irrigation efficiency of surface withdrawals
4. Field scale irrigation efficiency of groundwater withdrawals

Domestic water requirements:

1. Per capita water demand in the rural sector
2. Per capita water demand in the urban sector
3. % population with pipe water supply in the urban and rural sectors
4. % water withdrawals from the groundwater resources

Industrial water requirements:

1. Total industrial water requirement
2. % water withdrawals from the groundwater resources

Environmental Water requirements:

1. River flow requirement
2. Percentage of river flow to be met from the potentially utilizable water resources

Annex tables 5(a & b), 6(a & b), 7(a & b), 8(a & b) show the key drivers of agriculture, domestic, industrial and environmental water withdrawals of river basins for India and China.

Total water withdrawals of river basins in India and China are given in tables 9 (a & b)

Water Supply module has following key drivers.

1. Potentially utilizable surface water resources
2. Potentially utilizable groundwater resources
3. Water transfers in and water transfers out of basins
4. Environmental water demand
5. Reservoir storage
6. Evaporation from reservoir storage

Annex table 10 (a & b) gives utilizable water resources of river basins in India and China.

PODIUMSIM present three indicators to assess the extent of water development and water scarcity in river basins. These are degree of development (ratio of primary water withdrawals to utilizable water resources), depletion fraction (process and non-process evapotranspiration and flows to sinks) and groundwater abstraction ratio (ratio of groundwater withdrawals to total available groundwater resources). These ratios for the basins in India and China are given in tables 2 (a & b).

Table 2a. Degree of development, Depletion fraction and groundwater abstraction ratio of Indian River basins

River Basins	**Indicators**								
	Degree of development			**Depletion fraction**			**Groundwater abstraction ratio**		
	1995	**2025 Default scenario**	**Total growth**	**1995**	**2025 Default scenario**	**Change**	**1995**	**2025 Default scenario**	**Change**
	%	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
Indus	84	83	-1	93	93	0	70	82	12
Ganga	43	53	22	93	94	1	54	70	15
Bramhaputra	10	19	85	76	78	2	4	8	4
Barak & Others	14	31	115	82	81	-1	3	9	6
Subernarekha	41	57	37	91	92	1	49	69	20
Brahmani-Baitarni	25	33	31	92	93	1	54	72	18
Mahanadi	21	27	31	89	90	1	26	36	10
Godavari	27	35	29	92	92	0	36	48	12
Krishna	41	52	27	95	95	0	42	57	16
Pennar	108	112	3	91	92	1	63	76	13
Cauvery	48	57	21	93	94	1	52	67	15
Tapi	36	43	20	96	96	0	49	63	14
Narmada	20	28	40	94	94	0	30	42	12
Mahi	64	84	31	96	96	0	60	81	22
Sabarmati	67	82	22	95	95	0	91	107	16
West flowing rivers 1	150	154	3	93	93	0	194	210	16
West flowing rivers 2	22	33	47	94	94	0	40	62	22
East flowing rivers 1	45	55	23	86	87	1	24	32	8
East flowing rivers 2	76	88	17	92	93	1	46	59	12
India	42	51	21	93	93	0	51	64	12

Table 2b. Degree of development, Depletion fraction and groundwater abstraction ratio of Chinese river basins

River Basins	Indicators								
	Degree of development			Depletion fraction			Groundwater abstraction ratio		
	1995	2025 Default scenario	Total growth	1995	2025 Default scenario	Change	1995	2025 Default scenario	Change
	Km^3	Km^3		Km^3	Km^3		Km^3	Km^3	
Songliaohe	44	44	-1	84	87	2	57	66	9
Haihe	96	105	10	89	90	1	92	109	18
Huaihe	72	73	1	87	89	1	62	78	15
Yellow river	64	75	17	86	87	1	63	97	34
Yangtze river	40	44	11	70	72	2	10	30	20
Pearl river	40	47	17	69	70	2	6	22	15
Southeast	55	55	0	72	76	4	5	15	10
Southwest	25	28	11	73	76	3	3	7	4
Inland	44	48	8	95	96	1	42	53	11
China	47	51	8	78	80	2	41	58	17

Alternative scenarios

The default scenarios of the two countries show substantial grain production deficits (9% and 7% of the requirements for India and China). Though the degree of development under this scenario in both countries is close to 50 percent, several major basins will experience either physical water scarcity (high degree of development (IWMI 2000) or economic water scarcity (high growth of development).

The first alternative scenario can investigate alternative growth scenarios of several factors, especially

- population growth
- changes in consumption patterns including more livestock products
- locations and extent of crop area growth (irrigated and rainfed)
- cropping patterns change
- growth in crop yield increase in irrigated and rainfed agriculture

On the water demand side this scenario can investigate alternative options of expansion of groundwater irrigated area, increase in field scale efficiencies in meeting the required water withdrawals. The discussion on this scenario should include an assessment of implications of the above growth rates on the environmental sustainability of river basins.

The default scenario assumes bare minimum river flow requirements as environmental water requirements. The second alternative scenario can investigate alternative options of higher environmental water requirements and their impact on meeting water for people and national food production demand.

Third alternative scenario can investigate alternative options from the first two scenarios for attaining both national food security and environmental sustainability.

Annex table 1a. Grain requirements of **Indian river basins**

Basins	**Grain requirement of India (Grains include rice, wheat, maize, other cereals, Pulses)**		
	1995	**2025 Default scenario**	**Annual Growth**
	M MT	M MT	%
Indus	9.8	15.6	1.55
Ganga	74.6	118.8	1.57
Bramhaputra	6.7	10.0	1.34
Barak & Others	2.0	3.2	1.54
Subernarekha	3.0	4.6	1.41
Brahmani-Baitarni	3.4	5.1	1.40
Mahanadi	5.5	8.0	1.26
Godavari	15.5	22.8	1.31
Krishna	13.9	19.8	1.20
Pennar	2.9	3.9	1.02
Cauvery	6.6	8.7	0.93
Tapi	3.6	5.6	1.45
Narmada	3.6	5.6	1.45
Mahi	1.3	2.1	1.54
Sabarmati	1.2	1.9	1.47
West flowing rivers of Kutch & Saurastra Including Luni	11.9	19.0	1.58
West flowing rivers South of Tapi	10.5	14.0	0.98
East flowing rivers bet Mahanadi & Pennar	3.9	5.3	1.02
East flowing rivers bet Pennar & kanyakumari	7.9	10.2	0.88
Total (19 basins)	**187**	**284**	**1.39**

Annex table 1b. Grain requirements of **Chinese river basins**

Basins	**Grain requirement of China (Grains include rice, wheat, maize, other cereals, Pulses and roots and tubers (dry equivalent))**		
	2000	**2025 Default scenario**	**Annual Growth (%)**
	M MT	M MT	%
Songliaohe	38.4	49.7	1.03
Haihe	40.8	51.9	0.97
Huaihe	63.0	83.1	1.11
Yellow river	35.9	47.2	1.10
Yangtze river	139.2	183.4	1.11
Pearl river	47.7	65.4	1.27
Southeast	22.6	29.2	1.04
Southwest	6.8	9.2	1.24
Inland	9.0	12.6	1.35
Total (9 basins)	**403.4**	**531.8**	**1.11**

Annex table 2a. Grain crop area of Indan river basins

	Grain crop area								
River basin	**Irrigated area**			**Rainfed area**			**Total area**		
	1995	**2025 Default scenario**	**Annual growth rates**	**1995**	**2025 Default scenario**	**Annual growth rates**	**1995**	**2025 Default scenario**	**Annual growth rates**
	M Ha	**M Ha**	**%**	**M Ha**	**M Ha**	**%**	**M Ha**	**M Ha**	**%**
Indus	7.2	7.2	0.00	2.1	2.1	0.00	9.3	9.3	0.00
Ganga	22.9	31.2	1.03	25.3	19.5	-0.86	48.2	50.7	0.17
Bramhaputra	0.7	1.3	1.93	3.0	2.5	-0.68	3.8	3.8	0.00
Barak & Others	0.1	0.3	3.52	0.8	0.7	-0.78	0.9	0.9	0.02
Subernarekha	0.6	0.8	1.10	1.0	0.8	-0.83	1.6	1.6	0.01
Brahmani-Baitarni	0.9	1.2	1.05	1.6	1.2	-0.87	2.5	2.4	-0.06
Mahanadi	1.6	2.0	0.74	4.3	3.8	-0.41	5.8	5.7	-0.06
Godavari	2.7	3.9	1.22	8.7	7.8	-0.37	11.4	11.7	0.08
Krishna	2.4	2.9	0.68	6.3	4.9	-0.83	8.7	7.9	-0.34
Pennar	0.8	0.7	-0.26	0.7	0.6	-0.44	1.5	1.4	-0.35
Cauvery	1.0	1.1	0.18	1.5	1.1	-1.11	2.5	2.1	-0.52
Tapi	0.4	0.4	0.38	2.3	2.2	-0.21	2.7	2.6	-0.12
Narmada	0.9	1.2	1.03	2.8	2.5	-0.48	3.7	3.7	-0.05
Mahi	0.3	0.3	0.14	0.9	0.8	-0.30	1.1	1.1	-0.19
Sabarmati	0.2	0.2	0.11	0.5	0.5	-0.07	0.6	0.6	-0.02
West flowing rivers 1	2.2	2.1	-0.15	7.1	7.1	0.00	9.3	9.2	-0.03
West flowing rivers 2	0.8	1.2	1.35	2.6	1.4	-1.91	3.4	2.6	-0.82
East flowing rivers 1	1.1	1.3	0.45	1.3	1.0	-0.99	2.5	2.3	-0.25
East flowing rivers 2	1.4	1.5	0.15	1.2	0.8	-1.19	2.6	2.3	-0.40
India	48.1	60.8	0.78	74.1	61.2	-0.63	122	122	-0.01

Annex table 2b. Grain crop area of Chinese river basins

									Grain crop area
River basin	**Irrigated area**			**Rainfed area**			**Total area**		
	2000	**2025 Default scenario**	**Annual growth rates**	**2000**	**2025 Default scenario**	**Annual growth rates**	**2000**	**2025 Default scenario**	**Annual growth rates**
	M Ha	**M Ha**	**%**	**M Ha**	**M Ha**	**%**	**M Ha**	**M Ha**	**%**
Songliaohe	4.1	4.4	0.26	10.2	9.4	-0.32	14.3	13.8	-0.14
Haihe	5.7	5.7	0.01	3.2	2.5	-0.97	8.9	8.2	-0.32
Huaihe	10.9	10.8	-0.02	4.2	3.6	-0.59	15.1	14.4	-0.17
Yellow river	4.4	4.4	-0.01	7.1	6.4	-0.44	11.5	10.8	-0.27
Yangtze river	18.7	19.1	0.08	15.5	14.5	-0.27	34.2	33.6	-0.07
Pearl river	5.9	6.0	0.05	2.2	1.8	-0.89	8.1	7.7	-0.19
Southeast	3.2	3.0	-0.22	0.4	0.3	-1.91	3.6	3.3	-0.38
Southwest	1.3	1.3	0.09	1.0	0.8	-1.11	2.3	2.1	-0.40
Inland	2.7	2.8	0.13	0.2	0.1	-1.35	2.9	2.9	0.04
China	56.8	57.4	0.04	44.3	39.3	-0.45	100.	97.0	-0.16

Annex table 3a. Grain yields of Indan river basins

River basin	Grain crop yield								
	Irrigated yield			Rainfed yield			Average yield		
	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates
	Ton/ha	Ton/ha	%	Ton/ha	Ton/ha	%	Ton/ha	Ton/ha	%
Indus	4.8	6.7	1.10	1.4	1.56	0.43	4.0	5.53	1.05
Ganga	1.4	2.0	1.11	1.1	1.29	0.40	1.3	1.70	0.98
Bramhaputra	2.1	3.1	1.23	1.4	1.63	0.43	1.6	2.12	1.01
Barak & Others	1.1	1.7	1.38	1.0	1.09	0.42	1.0	1.26	0.86
Subernarekha	2.2	3.2	1.16	1.3	1.49	0.42	1.7	2.35	1.17
Brahmani-Baitarni	2.0	2.9	1.23	1.0	1.11	0.39	1.3	1.97	1.30
Mahanadi	2.1	3.0	1.21	1.0	1.11	0.35	1.3	1.76	1.02
Godavari	2.4	3.4	1.17	0.9	0.95	0.33	1.2	1.78	1.23
Krishna	2.7	3.7	1.12	0.8	0.91	0.31	1.3	1.97	1.29
Pennar	2.9	4.0	1.11	0.8	0.86	0.29	1.9	2.53	1.01
Cauvery	3.3	4.4	0.98	0.9	0.92	0.21	1.9	2.70	1.23
Tapi	1.9	2.3	0.67	0.8	0.92	0.35	1.0	1.14	0.54
Narmada	2.5	3.3	0.90	1.0	1.15	0.42	1.4	1.86	1.01
Mahi	2.6	3.3	0.85	0.7	0.84	0.39	1.2	1.49	0.78
Sabarmati	2.8	4.0	1.14	0.7	0.83	0.40	1.3	1.68	0.91
West flowing rivers 1	2.6	3.7	1.18	0.6	0.71	0.43	1.1	1.38	0.81
West flowing rivers 2	2.5	3.4	1.09	0.9	1.11	0.54	1.3	2.16	1.70
East flowing rivers 1	2.6	3.6	1.11	0.9	0.97	0.38	1.7	2.49	1.33
East flowing rivers 2	3.4	4.6	0.97	0.8	0.89	0.30	2.2	3.22	1.27
India	2.3	3.1	0.91	1.0	1.1	0.36	1.5	2.1	1.05

Annex table 3b. Grain yields of Chinese river basins

River basin	Grain crop yield								
	Irrigated yield			Irrigated yield			Irrigated yield		
	2000	2025 Default scenario	Annual growth rates	2000	2025 Default scenario	Annual growth rates	2000	2025 Default scenario	Annual growth rates
	Ton/ha	Ton/ha	Ton/ha	Ton/ha	Ton/ha	Ton/ha	Ton/ha	Ton/ha	Ton/ha
Songliaohe	4.5	6.2	1.29	4.1	4.6	0.43	4.2	5.1	0.75
Haihe	5.2	6.8	1.05	2.7	3.0	0.39	4.3	5.6	1.07
Huaihe	5.3	6.9	1.06	3.7	4.0	0.32	4.9	6.2	0.97
Yellow river	4.8	6.5	1.17	3.0	3.4	0.40	3.7	4.6	0.87
Yangtze river	4.4	5.7	0.99	3.1	3.3	0.34	3.8	4.6	0.81
Pearl river	3.7	5.0	1.19	3.1	3.4	0.34	3.6	4.7	1.07
Southeast	3.8	4.9	1.04	3.3	3.4	0.11	3.7	4.8	1.01
Southwest	3.4	4.5	1.10	2.5	2.8	0.37	3.0	3.9	0.98
Inland	4.7	6.4	1.21	0.9	1.0	0.38	4.5	6.1	1.28
China	4.6	6.0	1.08	3.3	3.7	0.39	4.0	5.1	0.90

Annex table 4a. Grain production of Indan river basins

River basin	Grain production								
	Irrigated production			Rainfed production			Total production		
	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates
	M MT	M MT	M MT	M MT	M MT	M MT	M MT	M MT	M MT
Indus	34.7	48.2	1.10	2.9	3.3	0.43	37.7	51.6	1.05
Ganga	32.4	61.3	2.15	28.8	25.0	-0.47	61.2	86.3	1.15
Bramhaputra	1.5	4.0	3.19	4.4	4.0	-0.26	5.9	8.0	1.01
Barak & Others	0.1	0.5	4.94	0.8	0.7	-0.37	0.9	1.2	0.87
Subernarekha	1.3	2.6	2.28	1.3	1.2	-0.41	2.7	3.8	1.18
Brahmani-Baitarni	1.7	3.4	2.29	1.6	1.4	-0.48	3.3	4.8	1.24
Mahanadi	3.3	5.9	1.96	4.3	4.2	-0.07	7.6	10.1	0.96
Godavari	6.6	13.5	2.41	7.5	7.4	-0.04	14.1	20.8	1.32
Krishna	6.4	11.0	1.81	5.2	4.5	-0.51	11.7	15.5	0.95
Pennar	2.3	2.9	0.84	0.6	0.6	-0.14	2.9	3.5	0.66
Cauvery	3.4	4.8	1.16	1.3	1.0	-0.90	4.7	5.8	0.71
Tapi	0.7	0.9	1.05	1.9	2.0	0.14	2.6	2.9	0.41
Narmada	2.3	4.0	1.94	2.9	2.8	-0.06	5.1	6.8	0.96
Mahi	0.7	0.9	0.98	0.6	0.7	0.09	1.3	1.6	0.58
Sabarmati	0.5	0.7	1.25	0.3	0.4	0.33	0.8	1.1	0.89
West flowing rivers 1	5.6	7.6	1.03	4.4	5.0	0.43	10.1	12.7	0.78
West flowing rivers 2	2.0	4.1	2.46	2.4	1.6	-1.38	4.4	5.7	0.86
East flowing rivers 1	3.0	4.8	1.56	1.2	1.0	-0.61	4.2	5.7	1.08
East flowing rivers 2	4.8	6.7	1.12	1.0	0.7	-0.89	5.8	7.4	0.86
India	113.3	187.8	1.7	73.4	67.5	-0.28	186.7	255.3	1.05

Annex table 4b. Grain production of Chinese river basins

River basin	Grain production								
	Irrigated production			Irrigated production			Irrigated production		
	2000	2025 Default scenario	Annual growth rates	2000	2025 Default scenario	Annual growth rates	2000	2025 Default scenario	Annual growth rates
	M MT	M MT	M MT	M MT	M MT	M MT	M MT	M MT	M MT
Songliaohe	18.4	27.1	1.55	41.6	42.8	0.11	60.1	69.9	0.61
Haihe	29.6	38.6	1.07	8.7	7.5	-0.58	38.3	46.1	0.75
Huaihe	58.1	75.2	1.03	15.4	14.4	-0.27	73.5	89.6	0.79
Yellow river	21.3	28.4	1.16	21.7	21.5	-0.04	43.0	49.9	0.60
Yangtze river	82.6	107.8	1.07	47.4	48.2	0.07	130.0	156.1	0.74
Pearl river	22.0	30.0	1.24	6.8	6.0	-0.55	28.8	35.9	0.88
Southeast	12.0	14.8	0.82	1.4	0.9	-1.80	13.4	15.6	0.62
Southwest	4.4	5.9	1.19	2.5	2.1	-0.74	6.9	8.0	0.58
Inland	12.8	17.9	1.35	0.2	0.1	-0.98	13.0	18.0	1.32
China	261.3	345.7	1.13	145.7	143.5	-0.06	407.0	489.2	0.74

Annex table 5a. Irrigation water requirements of Indian River basins

River Basins	Irrigation water withdrawals								
	Surface water			**Groundwater**			**Total**		
	1995	**2025 Default scenario**	**Annual growth rates**	**1995**	**2025 Default scenario**	**Annual growth rates**	**1995**	**2025 Default scenario**	**Annual growth rates**
	Km^3	**Km^3**	**%**	**Km^3**	**Km^3**	**%**	**Km^3**	**Km^3**	**%**
Indus	47.9	40.1	-0.59	31.0	30.0	-0.12	79.0	70.1	-0.40
Ganga	129.3	126.3	-0.08	114.7	132.9	0.49	244.0	259.1	0.20
Bramhaputra	7.8	12.6	1.60	0.2	0.4	1.83	8.1	13.0	1.60
Barak & Others	1.9	3.8	2.30	0.0	0.1	2.47	1.9	3.8	2.30
Subernarekha	3.8	4.2	0.32	1.7	2.1	0.68	5.6	6.4	0.44
Brahmani-Baitarni	4.6	5.0	0.30	3.4	4.2	0.76	7.9	9.2	0.50
Mahanadi	13.4	15.4	0.45	4.7	5.9	0.77	18.2	21.3	0.54
Godavari	22.4	24.7	0.33	14.9	18.3	0.70	37.3	43.0	0.48
Krishna	25.4	28.6	0.40	11.5	14.2	0.70	36.9	42.8	0.50
Pennar	8.1	7.0	-0.47	5.1	4.9	-0.13	13.2	11.9	-0.34
Cauvery	9.1	8.8	-0.11	6.8	7.6	0.36	15.9	16.3	0.10
Tapi	3.0	2.8	-0.20	3.9	4.4	0.40	6.8	7.1	0.15
Narmada	7.8	10.2	0.91	3.6	5.2	1.20	11.4	15.4	1.01
Mahi	2.0	2.2	0.26	2.7	3.5	0.89	4.7	5.7	0.63
Sabarmati	0.5	0.5	-0.11	3.0	2.9	-0.10	3.45	3.3	-0.10
West flowing rivers 1	2.8	2.5	-0.34	35.4	32.1	-0.33	38.2	34.6	-0.33
West flowing rivers 2	4.9	5.8	0.59	6.5	9.4	1.26	11.4	15.3	0.99
East flowing rivers 1	12.9	13.7	0.20	4.2	4.8	0.51	17.1	18.6	0.27
East flowing rivers 2	18.7	18.1	-0.11	10.1	11.0	0.31	28.8	29.2	0.04
India	326	332	0.06	263	293	0.37	590	626	0.20

Annex table 5b. Irrigation water requirements of Chinese river basins

River Basins	Irrigation water withdrawals								
	Surface water			**Groundwater**			**Total**		
	1995	**2025 Default scenario**	**Annual growth rates**	**1995**	**2025 Default scenario**	**Annual growth rates**	**1995**	**2025 Default scenario**	**Annual growth rates**
	Km^3	**Km^3**	**%**	**Km^3**	**Km^3**	**%**	**Km^3**	**Km^3**	**%**
Songliaohe	25.1	19.8	-0.94	15.2	13.9	-0.35	40.3	33.7	-0.71
Haihe	12.7	10.2	-0.88	19.0	18.0	-0.22	31.6	28.1	-0.47
Huaihe	38.8	29.9	-1.04	19.2	16.6	-0.58	58.0	46.5	-0.88
Yellow river	18.3	15.7	-0.59	6.8	6.6	-0.11	25.1	22.3	-0.46
Yangtze river	111.8	88.5	-0.93	1.8	1.5	-0.72	113.6	90.0	-0.93
Pearl river	44.1	34.8	-0.94	0.1	0.1	-0.73	44.2	34.9	-0.94
Southeast	22.6	17.9	-0.92	0.3	0.3	-0.71	22.9	18.2	-0.91
Southwest	8.5	7.8	-0.34	0.0	0.0	-0.13	8.5	7.8	-0.34
Inland	28.9	26.4	-0.37	10.8	10.6	-0.06	39.7	37.0	-0.28
China	311.0	251.1	-0.85	73.0	67.5	-0.32	384.0	318.5	-0.74

Annex table 6a. Domestic water requirements of Indian river basins

	Domestic water withdrawals								
River Basins	Surface water			Groundwater			Total		
	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates
	Km^3	Km^3	%	Km^3	Km^3	%	Km^3	Km^3	%
Indus	0.74	2.1	3.48	0.81	2.1	3.26	1.55	4.2	3.37
Ganga	4.89	14.1	3.60	5.27	13.6	3.22	10.2	27.7	3.41
Bramhaputra	0.31	1.0	3.90	0.42	1.0	2.99	0.7	2.0	3.41
Barak & Others	0.11	0.5	5.01	0.14	0.7	5.29	0.2	1.1	5.17
Subernarekha	0.19	0.6	3.73	0.21	0.6	3.59	0.4	1.2	3.66
Brahmani-Baitarni	0.16	0.5	4.17	0.22	0.6	3.46	0.4	1.2	3.77
Mahanadi	0.33	0.9	3.54	0.41	1.0	3.03	0.7	2.0	3.26
Godavari	0.74	2.5	4.20	0.96	2.3	2.97	1.7	4.9	3.55
Krishna	1.06	2.3	2.62	1.01	2.2	2.56	2.1	4.5	2.59
Pennar	0.18	0.5	3.51	0.23	0.6	3.40	0.4	1.1	3.45
Cauvery	0.49	1.1	2.78	0.49	1.0	2.48	1.0	2.1	2.63
Tapi	0.29	0.7	3.01	0.24	0.5	2.75	0.5	1.2	2.89
Narmada	0.21	0.6	3.58	0.26	0.6	2.97	0.5	1.2	3.26
Mahi	0.10	0.2	3.20	0.12	0.2	2.31	0.2	0.5	2.73
Sabarmati	0.25	0.4	1.92	0.40	0.6	1.38	0.6	1.0	1.60
West flowing rivers 1	0.81	2.4	3.67	0.78	2.3	3.61	1.6	4.6	3.64
West flowing rivers 2	0.92	1.9	2.43	0.68	1.4	2.37	1.6	3.3	2.40
East flowing rivers 1	0.27	0.7	3.07	0.31	0.7	2.73	0.6	1.4	2.90
East flowing rivers 2	0.70	1.4	2.25	0.60	1.1	1.89	1.3	2.4	2.09
India	12.7	34.5	3.37	13.6	33.1	3.02	26.3	67.6	3.20

Annex table 6b. Domestic water requirements of Chinese river basins

	Domestic water withdrawals								
River Basins	Surface water			Groundwater			Total		
	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates
	Km^3	Km^3	%	Km^3	Km^3	%	Km^3	Km^3	%
Songliaohe	0.1	0.1	1.5	4.1	6.5	1.5	4.21	6.6	1.5
Haihe	0.7	1.5	2.3	3.4	6.7	2.3	4.10	8.1	2.3
Huaihe	1.8	3.7	2.5	3.0	6.3	2.5	4.80	10.1	2.5
Yellow river	0.4	0.6	1.8	2.6	4.6	1.8	3.01	5.2	1.8
Yangtze river	15.1	23.3	1.5	1.7	2.6	1.5	16.79	25.9	1.5
Pearl river	7.9	16.4	2.5	0.6	1.2	2.5	8.51	17.6	2.5
Southeast	2.6	4.8	2.1	0.1	0.2	2.1	2.67	5.0	2.1
Southwest	0.6	1.4	2.7	0.1	0.1	2.7	0.70	1.6	2.7
Inland	0.4	1.0	2.6	0.2	0.5	2.6	0.68	1.5	2.6
China	29.6	52.8	2.0	15.8	28.7	2.0	45.5	81.5	2.0

Annex table 7a. Industrial water requirements of Indian river basins

River Basins	Industrial water withdrawals								
	Surface water			Groundwater			Total		
	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates
	Km^3	Km^3	%	Km^3	Km^3	%	Km^3	Km^3	%
Indus	0.63	1.92	3.80	0.63	1.6	3.11	1.3	3.5	3.47
Ganga	5.37	16.43	3.80	5.37	13.4	3.11	10.7	29.9	3.47
Bramhaputra	0.44	1.33	3.80	0.44	1.1	3.11	0.9	2.4	3.47
Barak & Others	0.09	0.28	3.78	0.09	0.2	3.09	0.2	0.5	3.45
Subernarekha	0.14	0.43	3.80	0.14	0.4	3.11	0.3	0.8	3.47
Brahmani-Baitarni	0.15	0.45	3.80	0.15	0.4	3.11	0.3	0.8	3.47
Mahanadi	0.40	1.22	3.80	0.40	1.0	3.11	0.8	2.2	3.47
Godavari	0.81	2.48	3.81	0.81	2.0	3.12	1.616	4.5	3.48
Krishna	0.91	2.78	3.80	0.91	2.3	3.11	1.8	5.1	3.47
Pennar	0.15	0.44	3.80	0.15	0.4	3.11	0.3	0.8	3.47
Cauvery	0.44	1.34	3.80	0.44	1.1	3.11	0.9	2.4	3.47
Tapi	0.22	0.68	3.79	0.22	0.6	3.10	0.4	1.2	3.46
Narmada	0.22	0.67	3.80	0.22	0.6	3.11	0.4	1.2	3.47
Mahi	0.16	0.48	3.80	0.16	0.4	3.11	0.3	0.9	3.47
Sabarmati	0.16	0.67	4.95	0.16	0.5	4.25	0.3	1.2	4.61
West flowing rivers 1	0.33	1.01	3.80	0.33	0.8	3.11	0.7	1.8	3.47
West flowing rivers 2	0.87	2.67	3.80	0.87	2.2	3.11	1.7	4.9	3.47
East flowing rivers 1	0.35	1.08	3.80	0.35	0.9	3.11	0.7	2.0	3.47
East flowing rivers 2	0.67	2.06	3.80	0.67	1.7	3.10	1.3	3.7	3.47
India	12.5	38.4	3.82	12.5	31.4	3.1	25.0	70.0	3.5

Annex table 7b. Industrial water requirements of Chinese river basins

River Basins	Industrial water withdrawals								
	Surface water			Groundwater			Total		
	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates
	Km^3	Km^3	%	Km^3	Km^3	%	Km^3	Km^3	%
Songliaohe	6.9	6.5	-0.24	7.7	8.9	0.58	14.5	15.3	0.21
Haihe	1.7	1.8	0.36	4.9	7.2	1.52	6.6	9.0	1.26
Huaihe	5.8	8.1	1.36	4.2	7.2	2.19	10.0	15.3	1.73
Yellow river	2.0	3.6	2.32	3.6	8.1	3.25	5.6	11.7	2.94
Yangtze river	47.7	69.0	1.49	2.9	12.8	6.18	50.6	81.8	1.94
Pearl river	14.7	22.2	1.67	1.2	4.8	5.58	15.9	27.0	2.14
Southeast	8.1	8.1	-0.02	0.3	1.2	6.45	8.4	9.3	0.42
Southwest	0.6	1.0	2.23	0.1	0.3	3.59	0.7	1.2	2.48
Inland	0.7	1.7	3.76	1.0	3.1	4.64	1.6	4.7	4.31
China	88.1	121.9	1.31	25.8	53.4	2.95	113.9	175	1.7

Annex table 8a. Environmental water requirements of Indian river basins

River Basins	Environmental water requirements								
	Minimum flow			**Other requirements**			**Environmental water requirements to be met from the potentially utilizable water resources**[2]		
	1995	**2025 Default scenario**	**Annual growth rates**	**1995**	**2025 Default scenario**	**Annual growth rates**	**1995**	**2025 Default scenario**	**Annual growth rates**
	Km^3	**Km^3**	**%**	**Km^3**	**Km^3**	**%**	**Km^3**	**Km^3**	**%**
Indus	46.0	46.0	0	0	0	0	0.00	0.00	0
Ganga	250.0	250.0	0	0	0	0	0.00	0.00	0
Bramhaputra	22.3	22.3	0	0	0	0	0.00	0.00	0
Barak & Others	1.7	1.7	0	0	0	0	0.00	0.00	0
Subernarekha	6.8	6.8	0	0	0	0	0.00	0.00	0
Brahmani-Baitarni	18.3	18.3	0	0	0	0	0.00	0.00	0
Mahanadi	50.0	50.0	0	0	0	0	0.00	0.00	0
Godavari	76.3	76.3	0	0	0	0	0.00	0.00	0
Krishna	58.0	58.0	0	0	0	0	0.00	0.00	0
Pennar	4.6	4.6	0	0	0	0	1.69	1.69	0
Cauvery	16.1	16.1	0	0	0	0	2.89	2.89	0
Tapi	11.4	11.4	0	0	0	0	3.07	3.07	0
Narmada	34.5	34.5	0	0	0	0	0.00	0.00	0
Mahi	3.1	3.1	0	0	0	0	0.00	0.00	0
Sabarmati	1.9	1.9	0	0	0	0	0.00	0.00	0
West flowing rivers 1	12.0	12.0	0	0	0	0	2.98	2.98	0
West flowing rivers 2	36.2	36.2	0	0	0	0	0.00	0.00	0
East flowing rivers 1	13.1	13.1	0	0	0	0	0.00	0.00	0
East flowing rivers 2	12.1	12.1	0	0	0	0	4.44	4.44	0
India	476.0	476.0	0	O	0	0	15.10	15.10	0

Annex table 8b. Environmental water requirements of Chinese river basins

River Basins	Environmental water requirements								
	Minimum flow requirement			**Other requirements**			**Environmental flow to be met from the potentially utilizable water resources**[3]		
	1995	**2025 Default scenario**	**Annual growth rates**	**1995**	**2025 Default scenario**	**Annual growth rates**	**1995**	**2025 Default scenario**	**Annual growth rates**
	Km^3	**Km^3**	**%**	**Km^3**	**Km^3**	**%**	**Km^3**	**Km^3**	**%**
Songliaohe	39	39	0	0	0	0	0	0	0
Haihe	12	12	0	9	9	0	9	9	0
Huaihe	31	31	0	8	8	0	8	8	0
Yellow river	23	23	0	23	23	0	23	23	0
Yangtze river	289	289	0	0	0	0	0	0	0
Pearl river	139	139	0	0	0	0	0	0	0
Southeast	77	77	0	0	0	0	0	0	0
Southwest	173	173	0	0	0	0	0	0	0
Inland	26	26	0	40	40	0	40	40	0
China	808	808	0	80.0	80.0	0	80.0	80.0	0

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[2] Minimum flow requirement of only few Indian river basins are more than the than the un-utilizable part of the surface runoff**.**

[3] Minimum flow requirement for all basins are less than the un-utilizable part of surface runoff.

Annex table 9a. Total water requirement for Agriculture, Domestic and Industrial sectors of Indian river basins

	Total water withdrawals								
River Basins	**Surface water**			**Groundwater**			**Total**		
	1995	**2025 Default scenario**	**Annual growth rates**	**1995**	**2025 Default scenario**	**Annual growth rates**	**1995**	**2025 Default scenario**	**Annual growth rates**
	Km^3	**Km^3**	**%**	**Km^3**	**Km^3**	**%**	**Km^3**	**Km^3**	**%**
Indus	49.3	44.1	-0.37	32.5	33.6	0.12	81.8	77.8	-0.17
Ganga	139.6	156.8	0.39	125.3	159.9	0.82	264.9	316.8	0.60
Bramhaputra	8.6	14.9	1.86	1.1	2.5	2.81	9.7	17.4	1.98
Barak & Others	2.1	4.5	2.58	0.3	0.9	4.40	2.4	5.5	2.83
Subernarekha	4.2	5.2	0.75	2.1	3.1	1.31	6.3	8.3	0.95
Brahmani-Baitarni	4.9	6.0	0.69	3.8	5.2	1.12	8.6	11.2	0.88
Mahanadi	14.2	17.5	0.71	5.5	7.9	1.22	19.7	25.5	0.86
Godavari	23.9	29.7	0.73	16.7	22.7	1.04	40.6	52.4	0.86
Krishna	27.3	33.7	0.70	13.4	18.6	1.10	40.8	52.3	0.83
Pennar	8.4	8.0	-0.18	5.5	5.9	0.25	13.9	13.8	-0.01
Cauvery	10.0	11.2	0.38	7.7	9.7	0.76	17.7	20.9	0.55
Tapi	3.5	4.2	0.61	4.3	5.5	0.77	7.8	9.6	0.70
Narmada	8.2	11.5	1.13	4.1	6.3	1.47	12.3	17.9	1.25
Mahi	2.3	2.9	0.83	3.0	4.1	1.12	5.2	7.0	0.99
Sabarmati	0.9	1.6	1.94	3.5	4.0	0.44	4.4	5.6	0.80
West flowing rivers 1	3.9	5.9	1.38	36.5	35.2	-0.13	40.4	41.1	0.05
West flowing rivers 2	6.7	10.4	1.48	8.0	13.0	1.62	14.7	23.4	1.56
East flowing rivers 1	13.6	15.5	0.44	4.8	6.4	0.96	18.4	21.9	0.58
East flowing rivers 2	20.1	21.5	0.23	11.3	13.8	0.65	31.5	35.3	0.39
India	351.5	405.0	0.47	289.4	358.5	0.72	640.0	763.7	0.59

Annex table 9b. Total water requirement for Agriculture, Domestic and Industrial sectors of Chinese river basins

	Total water withdrawals								
River Basins	**Surface water**			**Groundwater**			**Total**		
	1995	**2025 Default scenario**	**Annual growth rates**	**1995**	**2025 Default scenario**	**Annual growth rates**	**1995**	**2025 Default scenario**	**Annual growth rates**
	Km^3	**Km^3**	**%**	**Km^3**	**Km^3**	**%**	**Km^3**	**Km^3**	**%**
Songliaohe	32.0	26.4	-0.77	27.0	29.2	0.32	59.0	55.6	-0.24
Haihe	15.1	13.4	-0.45	27.2	31.8	0.62	42.3	45.3	0.27
Huaihe	46.4	41.7	-0.42	26.4	30.1	0.53	72.7	71.8	-0.05
Yellow river	20.6	19.9	-0.14	13.1	19.3	1.56	33.7	39.2	0.60
Yangtze river	174.7	180.9	0.14	6.3	16.9	4.02	181.0	197.7	0.36
Pearl river	66.7	73.4	0.39	1.9	6.1	4.77	68.6	79.5	0.59
Southeast	33.3	30.8	-0.30	0.7	1.7	3.65	33.9	32.5	-0.17
Southwest	9.7	10.2	0.20	0.2	0.4	3.34	9.9	10.6	0.28
Inland	30.0	29.0	-0.14	12.0	14.2	0.67	42.0	43.2	0.11
China	428.5	425.8	-0.02	114.7	149.6	1.07	543.2	575.4	0.23

Annex table 10a. Utilizable water resources of Indian river basins

River Basins	Utilizable water resources								
	Surface and Groundwater			Net water transfers in			Available water resources		
	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates
	Km^3	Km^3	%	Km^3	Km^3	%	Km^3	Km^3	%
Indus	60	60	0	0	0	0	60.3	60.3	0
Ganga	386	386	0	0	0	0	386.5	386.5	0
Bramhaputra	48	48	0	0	0	0	48.0	48.0	0
Barak & Others	10	10	0	0	0	0	10.2	10.2	0
Subernarekha	8	8	0	0	0	0	8.5	8.5	0
Brahmani-Baitarni	22	22	0	0	0	0	21.7	21.7	0
Mahanadi	64	64	0	0	0	0	63.6	63.6	0
Godavari	110	110	0	0	0	0	109.8	109.8	0
Krishna	78	78	0	0	0	0	77.9	77.9	0
Pennar	10	10	0	0	0	0	8.6	8.6	0
Cauvery	28	28	0	0	0	0	24.9	24.9	0
Tapi	21	21	0	0	0	0	18.1	18.1	0
Narmada	44	44	0	0	0	0	43.9	43.9	0
Mahi	7	7	0	0	0	0	6.6	6.6	0
Sabarmati	5	5	0	0	0	0	4.8	4.8	0
West flowing rivers 1	24	24	0	0	0	0	21.1	21.1	0
West flowing rivers 2	52	52	0	0	0	0	51.8	51.8	0
East flowing rivers 1	26	26	0	0	0	0	25.9	25.9	0
East flowing rivers 2	29	29	0	0	0	0	24.7	24.7	0
India	1032	1032	0	0	0	0	1017	1017	0

Annex table 10b. Total water requirement for Agriculture, Domestic and Industrial sectors of Chinese river basins

River Basins	Utilizable water resources								
	Surface and Groundwater			Net water transfers in			Available water resources		
	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates
	Km^3	Km^3	%	Km^3	Km^3	%	Km^3	Km^3	%
Songliaohe	95	95	0	0.0	0.0	0	95	95	0
Haihe	30	30	0	3.9	3.9	0	34	34	0
Huaihe	65	65	0	9.9	9.9	0	75	75	0
Yellow river	48	48	0	-7.2	-7.2	0	41	41	0
Yangtze river	360	360	0	-6.8	-6.8	0	353	353	0
Pearl river	130	130	0	0.1	0.1	0	130	130	0
Southeast	50	50	0	0.0	0.0	0	50	50	0
Southwest	30	30	0	0.0	0.0	0	30	30	0
Inland	65	65	0	0.1	0.1	0	65	65	0
China	873	873	0	0	0	0	873	873	0

Long Term Demand Projections for India- A Note

Yoginder K. Alagh

Introduction

While chairing the IFFPRI meeting session on water demand modeling in China and India the present author had argued that the projections for India are grossly underestimated as compared to those for other countries. Methodologically they need improvement and also show no awareness of excellent work done in India by modeling groups. Further discussions in the WWF at Kyoto, etc., confirms this. The present note outlines this position

The Planning Commission of India has correctly projected that the net area sown or arable land of the country will remain constant at 141 million hectares. Growth in net area sown at around 1% annual in the early period of planning fell to around 0.6% and then to 0.3% in subsequent decades and is now not growing at all. It is reasonable to assume that the geographical area of the country or the extensive land frontier for exploitation has reached its limits. This is an important issue, the implications of which are not being realized with the urgency they deserve, since at a basic level resource constraints of a more severe kind faced by certain East Asian economies are now being approached in India. Organizations, communities, households and individuals will have to grasp this fact and live with it.

The intensive frontier for land use, however, remains. It has been known for example, as noted by Chaddha, et. al., that cropping intensity depends on irrigation. Thus gross cropped area or harvested area has been shown in the past to be strongly determined statistically, in an econometric sense, by net irrigated area and irrigation intensity. Irrigation permits the possibility of multiple cropping by bringing additional land under cultivation and the same land to be used more than once. Also the application of new technologies in the past was related to assured water supply. The new technology, on account of its photo insensitivity properties, permits shorter duration crops, which also is associated with increase in cropping intensity. (For details of this relationship in agricultural planning and policy models, see Alagh, ESCAP, 1983). The use of this relationship has been used in Indian agricultural policy and plan models, since the mid-Seventies when the first agricultural sub-model of Indian planning was formulated for grain self reliance (See Alagh, et. al., Planning Commission, 1979). The parameters used in different plans were as follows;

Sr. No.	Plan	Additional Irrigation Utilisation (mn. hec.)	Additional Cropped Area (mn. hec.)	Elasticity of GCA w.r.t. GIA
0	1	2	3	4
1	Fifth	9.11	6.04	0.20
2.	Sixth	13.80	11.74	0.26
3.	Seventh(O)	10.90	10.00	0.31
4.	Seventh®	9.50	7.60	0.24

In the Nineties as we noted arable area has stopped growing and so the land constraint is far more severe. Growth will now have to be sourced from double cropping and yields.

This fundamental relationship can be used to project the intensive resource base of the economy. Table 1 shows that by the end of the decade India would have used up most of its balance water reserves, with the irrigated area reaching around 114 million hectares by 2010. (See Alagh, 1995, p. 395 and table). The projections for 2020 are a requirement of irrigation of 122 million hectares for irrigation (K. Chopra and B. Golder, Table 2.6)

Table 1. Land and Water resources perspective

Sl No	Variable	1991/2	1996/7	2001/2	2006/7
1.	Population (millions)				
	a. Planning Commission•	856	938	1016∂	1099
	b. UN (Unrevised)	874∂	955	1042	1130∂
2.	Net Area Sown (mn. hec.)				
	a. Planning Commission estimate	140	141	141	141
	b. Revised		141	141	141
3.	Gross area sown (mn. hec.)				
	a. Planning Commission estimate	182	191	197	203
	b. Revised	183	191	197	205
4.	Gross Irrigated Area (mn. hec.)				
	a. Planning Commission estimate	76	89	102	114
	b. Revised	64	78	92	107
5.	Cropping Intensity				
	a. Planning Commission estimate	1.30	1.35	1.40	1.44
	b. Revised	1.30	1.35	1.40	1.45
6.	Gross Irrigated Area as % of Gross Area Sown				
	a. Planning Commission estimate	41.5	46.9	51.7	56.1
	b. Revised	35.0	41	46	51

Source: Perspective Planning Division, Planning Commission FAO, Agriculture Towards 2010, Rome (Revised projections are tentative and are by the author.

Note: ∂ Interpolated or extrapolated from implied trends.

- Planning Commission estimates

Source: Uma Lele, et.al.. World Bank, 2001, Annex table by Y.K.Alagh

The projections assume a vastly improved performance on the land and water management frontiers. It needs to be remembered that the balance ground water reserves are now more limited. A very dramatic effort will be needed to harvest and carefully use the available water. Otherwise, the projected increase in cropping intensity will simply not take place. Cropping intensity increased from around 1.18 at the beginning of the Seventies to around 1.3 in the early Nineties. In the next two decades, this effort needs to be considerably strengthened, so that cropping intensity can increase from 1.3 to 1.5. Harvesting of rainwater, recycling water from agricultural drainage systems, more judicious use of water for cropping, will all be required. Non-agricultural use of water will have to be far more economical. The detailed exercise done for this study requires that in the sustainable scenario 35.83 BCM of water are saved by conjunctive use of surface and groundwater and 142 BCM through harvesting of runoff. (Chopra and Golder, Table 2.6)

Another way of looking at the severe land constraint is to see that a net area sown per person will go down from around 0.17 hectare to around 0.10 hectares. Gross area sown per person currently around 0.2 hectares will even, if cropping intensity increases very rapidly, go down to around 0.15 - 0.18 hectares. Table II given below summarises the findings on water requirements and water availability under alternative scenarios. Extrapolations of demand from different sectors show that if business as usual continues, quantitative shortages of water are likely to emerge. Declining water use efficiency in agriculture, increasing urbanisation and unregulated industrialisation pose significant challenges for the water sector in the future. Shortages, either of ground or surface water or both are likely to be pronounced in the states of Andhra Pradesh, Gujarat, Haryana, Punjab, Tamil Nadu and Maharashtra.

Table 2: Water Requirements: Different Scenarios (in BCMs in 2020)

	BAU	HG	SS (%)
Households	67.52	67.52	45.01 (4.66)
Power	8.19	12.29	5.00 (0.5)
Industry	27.91	41.58	27.72 (2.87)
Agriculture	677.30	804.20	768.37 (79.69)
Evaporation	42.00	42.00	42.00 (4.33)
Ecological	78.00	78.00	78.00 (8.09)
TOTAL	920.92	1005.59	964.09

Even with this a shortfall of irrigated land to the magnitude of 10 million hectares may arise. If this shortfall is made up for as in the HG scenario, a water shortage or deficit of 22% arises. The manner in which this translates into groundwater or surface water shortages in particular regions depends on policies pursued. The HG scenario also increases demands of the industry and power sectors, resulting in an overall increase in water requirement.

The sustainable scenario identifies interventions on the demand management and supply augmentation sides that can ensure that total water requirement is 964.09 BCMs in 2020. Of this, 79% shall come from the agricultural sector. In percentage terms, this is a decrease from current levels since requirements for non-agricultural sectors rise with industrialisation and urbanisation. Only 4.66% of total requirement comes from the household sector and another 3.37% from industry and power sector. This study provides additionally for a requirement of 78 BCM to maintain base non-seasonal flow in rivers and 42 BCMs for evaporation losses. With total supply from ground and surface water at 1110.566 BCMs, one can argue that the position at the aggregate level shall be manageable. Such a presumptions, assumes however that interventions suggested to achieve improved water use efficiency shall be undertaken and shall be successful. In frozen water use efficiency in agriculture scenario, acute shortages may arise even at the aggregate level.

By 2020, Chopra and Goldar estimate a BAU Scenario:
"In such a scenario, overall water shortage or deficit is only of 2%. This is accompanied by an under utilisation of surface water capacity of 21% (due to low water use efficiency) and an over-extraction of ground water of 25%. Such an unbalanced growth shall itself be the source of a considerable amount of unsustainability.

The second interpretation of the BAU scenario is motivated by the need to estimate regional shortages or surpluses. The BAUST or the business-as usual with the state level estimates is made by assuming that surface and ground water development follow the trend extrapolated from the past.[4] The regional analysis reveals that over-extraction of groundwater shall emerge in eight states. In addition to Gujarat, Haryana, Punjab and parts of Uttar Pradesh which are characterised as areas with over-use of ground-water, Andhra Pradesh, Maharashtra and Tamil Nadu are also expected to be subject to over-extraction. Surface water shortages may start emerging in some states such as Gujarat, Bihar, Maharashtra and Orissa. " and again taking population projections and the energy models as developed by the AITD urbanisation study and suitable assumptions they estimate:

"The total requirement for households, power and industry is 103.62 BCMs in the BAU scenario. Adding evaporation loss and ecological requirement we obtain a total requirement of 223.62 BCMs for requirements other than agriculture."

Chopra and Goldar also estimate a high growth scenario. Then:
"The high growth scenario at the national level implies a rate of growth of agriculture of 4.98% per annum with the food grain sector growing at 2 to 2.4% p.a. and the non-food grain sector at 7.69 to 9.22% p.a. Irrigated land requirement increases to 122 million hectares. With present levels of water use efficiency,

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[4] Following such a methodology implies that the two estimates should not be compared. The BAUST estimate is motivated by the need to identify regional shortages or surpluses of water, while the BAU estimates determine the impact of food security objectives on water demand.

water requirement increases to 804.2 BCMs. This implies a shortfall/water deficit of 22%. The manner in which this translates into over-extraction of groundwater or other indices of unsustainability depends on policies pursued and cannot be ascertained. It is, however, clear that both the high growth and BAU scenarios are likely to result in unsustainable demand for water of one kind or the other in the absence of specific investments and policies directed at improvement of water-use efficiency and other sustainability promoting measures.

The requirements of the households, power and industry sectors likewise add up to 120.57 BCMs in the HG scenario as against 103.62 BCMs in the BAU scenario.

Regarding the quality of water they say

"An important issue which our analysis brings out is that at present levels of urban wastewater and effluent treatment, water quality will deteriorate significantly, impacting availability as well in certain areas. The reduction in water availability due to quality problems is expected to be substantial.[5] We use this evidence to underscore the need for and the corresponding benefit from "sustainability investments".

Chopra and Godar then develop a sustainable policy scenario:
"It is clear from the above analysis that, in order to achieve sustainable water development, consistent with sectoral requirements arising from a sustained 7 to 8 % annual growth in GDP and other accompanying changes in the economy, a large number of interventions shall be required. These interventions could be technological, institutional, or supply augmenting possibilities. Table I list some interventions for sustainability we suggest, including watershed management, drip irrigation, and institutional arrangements, such as water users' associations, that help in more efficient use of water. Some of these have been experimented with in different contexts and we estimate (on the basis of existing studies) the extent to which they can be expected to spread over the next twenty years. Corresponding costs are also worked out. These are, in other words, the costs to be borne for ensuring sustainable use of water. Other interventions suggested involve costs which are either difficult to measure, involve uncertainty or are not only economic costs but also perhaps political in nature. Further, interventions are also classified according to whether they are to be undertaken on presently irrigated land which is privately owned, or consist of interventions on land (possibly under private, common or government ownership) to be brought under irrigation."

Table 3. Nature of Interventions under Sustainable Scenario

Nature of interventions	Sector	Water Saving/Addition (in BCMs)
Demand management/ Recycling technology	Households	22.51
	Power sector	7.29
	Industry	13.86
	Agriculture	35.83
Supply Supplementing	Additional Runoff Capture	142.00
Total Water Saving/ Augmentation		221.49

Much the same kind of approaches and projections have been made by the National Commission on Perspectives for Water Development as shown below:

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[5] See Das and Dipankar (2000) Using a more stringent standard for irrigation water, this study estimates that in some areas with a high level of urbanisation, only 54% of the groundwater in underlying aquifers shall be fit for use for irrigation. This study was commissioned by IEG as part of the current UNU study.

Table 4. Water Requirement for Different Uses

S.No	**Uses/year**	**Year 2010**			**Year 2025**			**Year 2050**		
		Low	**High**		**Low**	**High**		**Low**	**High**	
		Km^3	**Km^3**	**%**	**Km^3**	**Km^3**	**%**	**Km^3**	**Km^3**	**%**
	Surface Water									
1.	Irrigation	382	391	53	360	389	46	375	463	39
2.	Domestic	23	24	3	30	36	4	48	65	6
3.	Industries	26	26	4	47	47	6	57	57	5
4.	Power	14	15	2	25	26	3	50	56	5
5.	Inland Navigation-in additional for ecological need	7	7	1	10	10	1	15	15	1
6.	Environment (2) Ecology	5	5	1	10	10	1	20	20	2
7.	Evaporation	42	42	6	50	50	6	76	76	6
	Total	499	510.1	70	532	588.3	67	641.1	751.7	64
	Ground Water									
1.	Irrigation	184	188	26	211	229	27	253	344	29
2.	Domestic & Municipal	19	19	3	25	28	3	42	46	4
3.	Industries	11	11	2	20	20	2	24	24	2
4.	Lower	4	4	1	6	7	1	19	14	1
	Total	217.7	221.9	30	262.3	281.7	33	331.9	428.3	36
	Grand Total	717	732	100	794	850	100	973	1180	100

Source: Government Of India, National Commission on Perspectives for Water Development

While some of the interventions suggested are well known, others involve fresh thinking, hence we discuss them in some detail, with theoretical and experience based analysis. The technology interface is important, both for land and water management and for cropping and non-crop farm systems that are optimal, in this class of issues. While a lot of research has been done and is available, (Alagh, FAO/ UNESCO, 2002) the real issues are policy rules for fast replicability of existing knowledge and success stories. Community institutions have to be at the heart of this process. The projects examined have varied considerably. Watershed development, for settled agriculture alternately tree crops, reclamation of saline lands, farmers run lower level irrigation systems, aquifer management in difficult situations, like coastal aquifers, tribal irrigation cooperatives, tank irrigation have all been reported as success stories and studied. Chaddha has generalized from them. The question is replicability on a larger scale. We have (YK Alagh,2003) tried to set out some policy rules which we argued if applied in functioning policies may reverse the tide .

It is interesting that in recent global meetings the same strategy is being advocated. India is playing a strong role in such advocacy. For example the Expert Round Table organized by India and the UN to operationalise the new initiatives required at the Johannesberg Meeting on RIO PLUS 10 said the following:

- *Improve* investment processes in developing countries and countries with economies in transition to facilitate access to credit lines as well as to preferential terms of financing and of providing funds for collateral support systems and sharing of investment risk. In this context, provide securities for local institutions involved in infrastructure development and specific knowledge based activities to support sustainable economic growth, through, for example, creation of collaterals, interest differentials and trading of financial papers. These processes should be targeted, amongst others, to artisan and producer groups linked with local and global markets, local government agencies providing social and economic infrastructure, and farming and rural communities.

- *Improve* coordination among international financial institutions and redirect funds to sustainable development projects.
- *Develop* new or *strengthen* existing mechanisms such as the Clean Development Mechanism (CDM), to finance or re-finance community projects in rural areas aimed at land and water development, agricultural diversification and agro-processing, development of infrastructure, trade, and rural energy supply.
- *Study* for the purpose of replication, existing models for providing access of rural communities to ICTs in order to enhance the level of information in rural communities on productions, crops, markets, prices and technologies .

India has raised this issue in the WTO negotiations also as the following draft of the Special Committee of Agriculture under the chair of Stuart Harbinson on support to Farmers and Producer s and Cooperatives in rural development infrastructure showed. The opportunities in the Harbinson Draft are as follows:

"Attachment 9
Article 6.2 of the Agreement on Agriculture

- ***Possible amendments for further consideration (changes in italics)***
- In accordance with the Mid-Term Review Agreement that government measures of assistance, whether direct or indirect, to encourage agricultural and rural development are an integral part of the development programmes of developing countries, *and in accordance with paragraph 13 of the Doha Ministerial Declaration the following measures* in developing country Members shall be exempt from domestic support reduction commitments *to the extent that these commitments* would otherwise be applicable to such measures:
  1. investment subsidies which are generally available to agriculture
  2. agricultural input subsidies generally available to low-income or resource-poor producers
  3. domestic support to producers to encourage diversification from growing illicit narcotic crops *or those whose non-edible or non-drinkable products, being lawful, are recognized [by WHO] as harmful for human health*
  4. *subsidies for concessional loans through established credit institutions or for the establishment of regional and community credit cooperatives*
  5. *transportation subsidies for agricultural products and farm inputs to remote areas*
  6. *on-farm employment subsidies for families of low-income and resource-poor producers*
  7. *government assistance for conservation measures*
  8. *marketing support programs and programs aimed at compliance with quality and sanitary and phytosanitary regulations*
  9. *capacity building measures with the objective of enhancing the competitiveness and marketing of low-income and resource-poor producers*
  10. *government assistance for the establishment and operation of agricultural cooperatives*
  11. *government assistance for risk management of agricultural producers and savings instruments to reduce year-to-year variations in farm incomes*
  12. *Domestic support meeting the criteria of this paragraph shall not be required to be included in a Member's calculation of its Current Total AMS"*

It has been shown recently that such work is important in sustainable development policies for the subcontinent (Y.K.Alagh,2004)

References

Alagh, Y.K.,,2000, Global Sustainable Future and Developing Countries, Tokyo, UNU/IAS.

Alagh , Y.K. 2000, Sustainable Development: India 2020, Tokyo, UNU/IAS

Alagh, Y.K. 2003, Emerging Institutions for Rural Development, in Chopra, K., CHH Rao and R.P. Sengupta, ed., Water , Sustainable Livelihood and Eco System Services, Concept, Delhi

Alagh, Y.K. 2004, Our Common Future, Working Paper, Kieo University 21st Century Progaramme, Japan

Cosgrove, W., and F. Rijsberman, 2000, The Challenge of Making the World Water Vision A Reality, Tokyo, UNU/IAS.

Chopra, K., and Golder, B., 2000, Sustainable Framework for Water, UNU, IAS

Lele, U., N. Kumar, Y. Alagh, N. Saxena, and K. Mitra, 2000, Alleviating Poverty through Forestry Development, Washington, World Bank.

United Nations, UNU/IAS, Papers read at Conference on Sustainable Future of the Global System, Tokyo. Ed., Fu Chen Lo, H.Tokuda and N.S.Cooray

Application of CPSP Hydrological Model in Qiantangjiang River Basin

Jianxin Mu[1], *Zhanyi Gao*[1], *Shaoli Wang* , *Yu Liu*[1]
China Institute of Water Resources and Hydropower Research, Beijing 100044, China

ABSTRACT

CPSP hydrological model was used in this paper to simulate the water balance and analyze the impact of land and water use and climate changes on resources in Qiantangjiang River Basin. The model was run on monthly basis and calibrated by comparing the calculated and observed monthly outflow, total groundwater recharge and withdrawal, the withdrawal for irrigation, and the total withdrawal for irrigation and D & I at present (2000) and applied to simulate the past (1980) conditions and for all the future scenarios that were developed to analyze effects of water policies and sectoral demands of water. It showed from the result that CPSP model is a very useful tool for basin-level water assessment, especially for humid areas. As Qiantangjiang is a water rich river basin in China, there is even no groundwater withdrawal for irrigation so far. Therefore, the potentials of groundwater for both agricultural and D & I uses should be excavated. However, with the increased proportion of groundwater return, groundwater quality also faces huge challenges. How to manage the water and land well is inevitably a subject to us.
Key words: CPSP model, land and water use, scenarios

INTRODUCTION

Qiantang River Basin, which lies between Longitude 118º East to 121º East and Latitude 28º North to 31º North, extends across Zhejiang, Anhui, Jiangxi, Fujian and Shanghai five provinces/municipalities with a total of 55558 Km^2 of catchment area. The catchment area involved in this report is 35500 Km^2 in the upstream of Hangzhou Gate within the boundaries of Zhejiang Province that are under the jurisdiction of Hangzhou, Quzhou, Jinhua, Shaoxing and Lishui five municipalities/prefectures totally 27 counties/cities/districts (hereinafter the scope of Qiantang River Basin). It borders on Xianxia Mountain and spreads into Min River of Fujian Province in the south, Huaiyu Mountain and Le'an River and Xin River, water system of Poyang Lake of Jiangxi Province in the southwest, Huang Mountain and Tianmu Mountain and Qingyi River of Anhui Province and Taihu Lake of Zhejiang Province in the north, Bay of Hangzhou in the northeast, Siming Mountain and Yong River and Tiantai Mountain and Jiao River in the east, and Xianxia Mountain and Ou River in the southeast.

According to the statistical data in 2000, the total population in Qiantang Basin is 10.67 million (accounting for 24% of the total of Zhejiang Province) and cultivated area 0.4240 Mha (accounting for 11.9% of the total land area in Qiantang Basin and 31% of the total cultivated area of Zhejiang Province), including 0.3604 Mha of paddy field and 0.0636 Mha of upland. The per capita cultivated area in this river basin is 0.04 ha and garden plot 0.1309 Mha, accounting for 3.7% of the total land area.

Qiantang River Basin comes under subtropical monsoon climate with well-marked four seasons. The average annual precipitation is between 1200 mm and 2200 mm and evaporation between 800 mm and 1000 mm. The total water resources in Qiantang River Basin (upstream of Hangzhou Gate) is 38.64 billion m^3, including 7.71 billion m^3 of unconfined groundwater resources, accounting for 20% of the total amount.

Qiantang River Basin has favorable natural conditions and rich agricultural resources. Intensive cultivation and combination between agriculture and husbandry etc., traditional agriculture have been formed in its long history of development. It also has great potentialities in the development of forestry and fishery and is always an important area for the all-round development in agriculture, forestry, sideline and fishery in Zhejiang Province and Anhui Province. Its cultivated area in 2000 is 0.4240 Mha, accounting for 11.9% of the total land area and the per capita cultivated area 0.04 ha, garden plot 0.1309 Mha, accounting for 3.7% of the total land area. The main land uses in Qiantang Basin is shown in Table 1.

Table 1 Main land uses in Qiantang Basin in 2000

Land use(Million ha)	Upstream	Downstream
Total land area	2.520	1.030
Available cultivated area	0.2888	0.1352
Gross cropped area	0.5776	0.2704
Farmland irrigated area	0.2679	0.1254
Fruit irrigated area	0.1052	0.0256
Forest area	0.9673	0.4527

Paddy rice, wheat, barley, maize, soybean and potato are the staple crops in this river basin as well as tea, rape, cotton, sugarcane and medical materials etc., cash crops and tea-oil tree, orange, bayberry, grape, persimmon and loquat etc., cash trees. Jinqu Basin is the second commodity grain base where the production of cotton occupies a pivotal position in Zhejiang Province. With the development of town/township enterprises in recent years, the economy here develops rapidly. In 2000, the gross value of agricultural and industrial output is RMB 258 billion (US$31.1 billion), accounting for 17% of the total and and Jinqu has become one of the economic development regions with much potentiality in Zhejiang Province.

The model was calibrated for the present conditions and applied to derive responses corresponding to past and future scenarios using monthly time steps. Studies were done at the sub basin level. The basin was divided into two sub basins which are third-level zones to allow segregation of areas having similar hydrologic and water use attributes. The two sub basins studied are:

SB1 : Upstream of Fuchunjiang Reservoir
SB2 : Downstream of Fuchunjiang Reservoir

The present (year 2000) socio-economic conditions, including population, cultivated area, orchard area and equivalent sheep in the two SBs are shown in Table 2.

Table 2 Socio-economic Conditions of SBs in Qiantang Basin

SB	Population (million)			Cultivated area (Km^2)			Orchard (Km^2)	Equivalent sheep (million)
	Urban	Rural	Subtotal	Paddy	Upland	Subtotal		
SB1	2.41	4.93	7.33	2403.52	484.82	2888.34	1052.59	9.00
SB2	1.15	2.19	3.34	1200.66	151.21	1351.87	256.08	2.82

Total	3.56	7.11	10.67	3604.18	636.03	4240.21	1308.67	11.82

The SB1 comprises around two thirds of the surface storages and land area. The soil moisture capacity was varied for each type of land use, and values consistent with the likely root zone depths and field capacities were used.

The water storage and water supply capacities of various projects for the present conditions, which are the key factors to check the rationalities of surface storage filling and depletion and area under reservoir, are detailed in Table 3.

Table 3 Water Supply Capacities of Various Projects for the Present Conditions (Million m^3)

SB	Liver storage of medium and large reservoirs	Live storage of small reservoirs	Water supply capacity of water withdrawal projects	Water supply capacity of groundwater projects	Total live storage
SB1	1142.56	690.57	1169.51	212.16	1833.13
SB2	81.3	195.89	729.39	72.89	277.19
Total	1223.86	886.46	1898.9	285.05	2110.32

LAND USE TYPES

From Table 2 it can be seen that paddy rice is the major crop in this basin, accounting for 85% of the total cultivated area. Fruit and rapeseed etc., cash crops are also very common, the cropping area of rapeseed in 2000 is 733 Km, amounting to 12% of the total cropping area. Following fourteen standard land-use types were used in the model. It should be specially noted that the area under reservoirs (including ponds and swamps) is nearly closed to the total cultivated area because these reservoirs also take the functions of flood control and power generation besides irrigation and D & I water supply. Moreover, with the rapid socio-economic development and adjustment of cropping pattern, more and more farmlands were converted into ponds for fisheries since 1980 when the reform and opening-up policies were carried out broadly. Table 4 gives land categories used in the model.

SCENARIOS STUDIED

The various scenarios studied are showed in table 5. Table 6 provides a clear benchmark in various scenarios. The land use data used in different scenarios depicted in Figure 4.1.

Table 4 Land categories used in the model

P1	Forest and miscellaneous trees
P2	Permanent pastures
P3	Land not available for cultivation, waste, & fallow
P4	Land under reservoirs
P5	Rain-fed soybean and wheat
P6	Rain-fed fruit
P7	N/E
P8	N/E
P9	N/E
P10	N/E

P11	Irrigated double cropping of rice
P12	Irrigated early rice and autumn maize
P13	Irrigated single cropping of rice and rapeseed/vegetable
P14	Irrigated t sugarcane and barley
P15	Irrigated cotton and wheat
P16	Irrigated sweet potato and vegetable
P17	Irrigated vegetable
P18	Irrigated fruit

The model was run on monthly basis, for average rainfall and ET_0 conditions for the past, present and future scenarios.

Table 5 Description of scenarios

Sr. No.	Abbreviation	Explanatory notes
1.	**Past** (1980)	The social economy developed quickly since the implementation of the reform and opening-up policies after 1980.
2.	**Present** (2000)	To date.
3.	**Future I** (2025) B as U	Business as Usual. With increased water infrastructure (and small import), Irrigation expansion with cropping pattern same as at present. Proportion of surface & groundwater irrigation same as at present
4.	**Future II** (2025)	With no expansion of water infrastructure (and small import), shift in cropping pattern, better water management
5.	**Future III** (2025)	With increased water infrastructure (and small import) and irrigation expansion, shift in cropping pattern, more groundwater use and better water management
6.	**Future IV** (2025)	With increased water infrastructure (and small import), no irrigation expansion, shift in cropping pattern, more industries, more groundwater use, export water and better water management
7.	**Future V** (2025), agri. seasonal shift	With increased water infrastructure (and small import), no expansion of irrigation, more industries, more GW use, better water management

Table 6 Future Scenario Comparison in CPSP Model

Future Scenario	**Additional water infrastructure**	**More irrigation area**	**Industry**	**Water management**
FI (BAU)	Yes	Yes +No shift in CP	Normal	As usual
FII	No	No expansion + Shif in CP	Normal	Better
FIII	Yes	Yes + Shift in CP	Normal	Better + More GW use

FIV	Yes	No expansion +Shift in CP	More	Better + More GW use +Export
FV	No	No expansion + Shift in CP	Normal	Better + More GW use

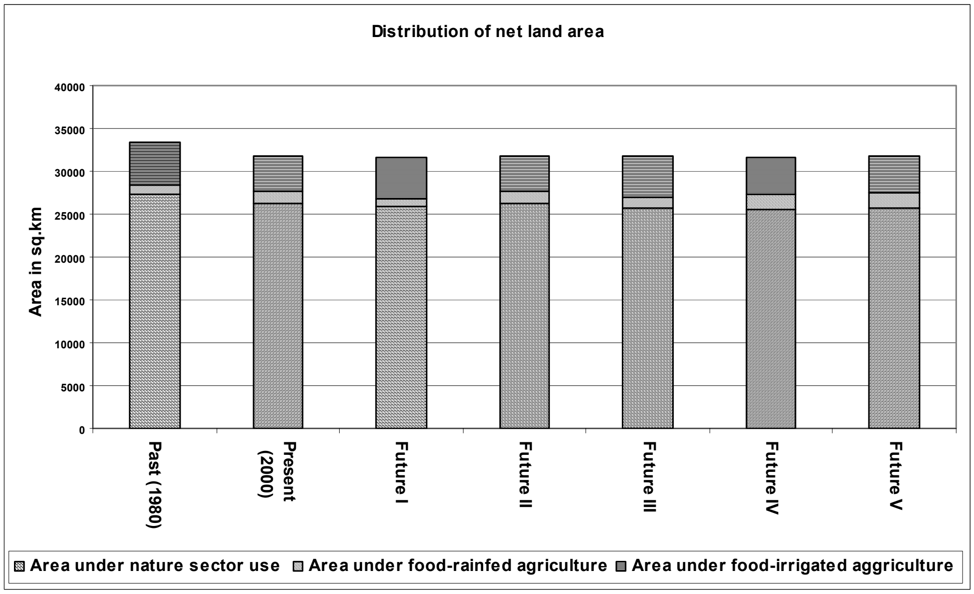


Figure 4.1. Distribution of the net land area in Qiantang Basin

MODEL CALIBRATION

Because Qiantang Basin is an area with abundant water resources, surface water resources are the major water source for agriculture, domestic and industry, while groundwater resources have not been used in irrigation so far, except a little in D & I use. Consequently, there are no observed groundwater fluctuation data in this basin. The model was calibrated and validated by adopting the following steps with the available data computed by the model and estimated by Qiantang Basin Management Bureau for the present conditions.

1. Comparing the total monthly outflow (surface runoff plus base flow) of SB1 and SB2 with the observed monthly runoff.
2. Comparing the natural recharge to groundwater as in the model, as a percentage of rainfall, and to compare this percentage with the generally adopted norms.
3. Comparing the total groundwater recharge and withdrawal, as computed by the model, with the estimates of the Qiantang Basin Management Bureau.
4. Comparing the withdrawal for irrigation, and total withdrawal for irrigation and D & I, as computed by the model, with the estimates of the Qiantang Basin Management Bureau.

As the boundaries of this river basin are dictated by the administrative units (municipalities) but not hydrologic units, therefore there could be natural inflows from outside the study area to the study area and similarly there would be some flows from the study areas which did not go to the sea to pass to other administrative units. In the assessment as made, this point has already been considered by using only the proportioned flow as generated from the study area.

In terms of monthly outflow to sea, this model has a very good match for the present conditions, where the difference between the total outflows computed by the model and observed by local hydrological stations is only around 0.5%. Figure 2 shows the computed and observed average monthly values.

Regarding total recharge to groundwater and total withdrawals for irrigation and D & I, the differences between the computed and estimated also are not very high, which are only 14.18% and 8.2% respectively. Therefore, generally speaking, this model has a comparatively good match in the humid area. The main computed and estimated results for the present conditions are shown in Table 7.

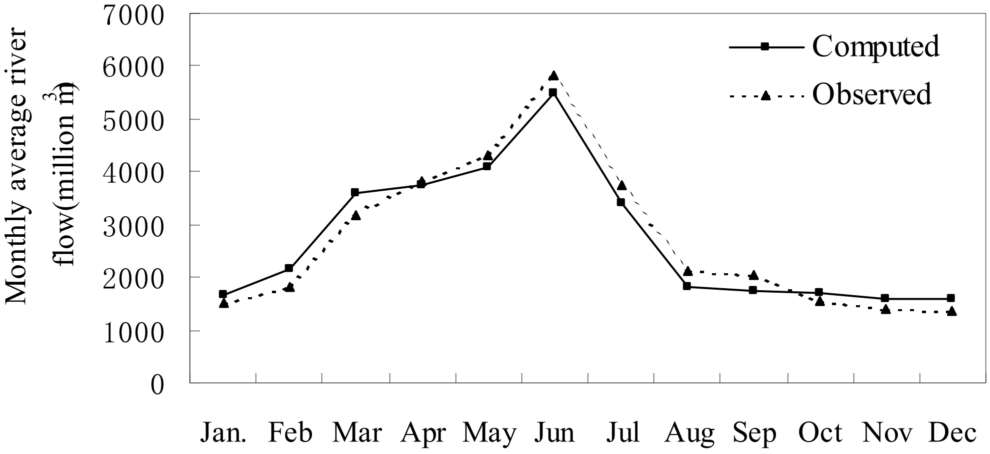


Figure 2 **Comparison of Computed and Observed Average River Flow**

With the above calibration, the general validation of the model was accepted with the following values of main parameters:

1. Soil moisture storage capacity: varies with soil type and land use: 200 mm for forests, 100 mm for pastures and fruit, 75mm for agricultural lands (but 150 mm for paddies) and 40 mm for bare lands or land put to other uses. Higher capacity values would lead to higher evapo-transpiration and lower flows after rainfall has ceased, thus giving a better calibration but values higher than these were not tried as such capacities were unlikely to be available.

Table 7 Comparison of Computed and Observed Results for the Present Conditions (million m^3)

Items	Computed by the model	Estimated	Difference (%)
Percentage of groundwater recharge from rainfall	9	8	10.92
Total Recharge to groundwater	7451	6525	14.18
Groundwater fluctuation within the year	2451	NA	
Total outflow to sea	32542	32703	-0.5

Withdrawal for irrigation	4497	5028.8	-10.6
Withdrawal for irrigation and D&I	5909	6436.0	-8.2

2. The excess water was divided assuming that 85 percent yields to surface and sub surface (or quick runoff) flow and the rest 15 percent yield to groundwater. With this assumption, reasonable annual recharge was realized.
3. The exponential index, depicting the reduction of evapo-transpiration rate with reducing availability of soil moisture in the relationship was kept at 0.6.
4. A groundwater recession coefficient of 0.27 allowed the persistence of good base flows. As there is no much groundwater withdrawals in this river basin, the base flows both in the prototype and in the model are very high, particularly from May to November.
5. Qiantang Basin is a humid area in the south of China; therefore soil moisture capacity is used as the initial soil moisture of the first month –January for each land parcel.

SIMULATION OF PAST AND FUTURE CONDITIONS

The model was applied to simulate the past (1980) conditions and for all the future scenarios enumerated above with average rainfall and ET_0.

The inputs and outputs of this hydrologic model are all in million cubic meters. The abstracted results are presented in the following Tables 8 and Table 9 give the surface and ground water balances at the basin level.

Table 8. Annual water balance for surface water resource system - Qiantang basin (Steady state, average rainfall) (Million m^3)

	Past (1980)	Present (2000)	Future I (2025) B as U, with increased irrigation infrastructure	Future II (2025), no expansion of irrigation infrastructure, better water management	Future III (2025) same as FII, with more groundwater use and better water management	Future IV (2025), more industries, more groundwater use, export water and better water management	Future V (2025) , No expansion of irrigation, more GW use, better water management
Inputs							
Quick runoff from rainfall	29679	29522	28572	28676	28525	28579	28847
Base flow	7980	7341	7387	6550	6242	5999	6603
Returns to surface from surface irrigation	1210	972	1068	881	810	694	792
Returns to surface from GW irrigation	0	0	0	0	26	22	24
Returns to surface from D&I withdrawals	311	507	990	990	990	1363	1363
Sub-total, returns to surface	1521	1479	2058	1871	1826	2079	2179
Imports	0	0	56	56	56	56	56
Total inputs	39180	38341	38073	37152	36649	36713	37685
Outputs							
Surface withdrawals for irrigation in the basin	5370	4497	4701	3218	2960	2477	3573
Surface withdrawals for D&I in the basin	820	1302	2511	2511	2511	3448	3448
Total surface wirhdrawals, for use in the basin	6190	5799	7212	5729	5471	5925	7021
Natural and induced recharge from river to GW	0	0	0	0	0	0	0
Outflow to sea	32990	32542	30861	31423	31178	30518	30664
Export	0	0	0	0	0	270	0
Total output	39180	38341	38073	37152	36649	36713	37685

Table 9. Annual water balance for groundwater - Qiantang basin (Steady state, average rainfall)(million m^3)

	Past (1980)	Present (2000)	Future I	Future II	Future III	Future IV	Future V
Inputs Natural recharge from rainfall	5182	5143	4966	4984	4958	4967	5015
Returns to GW from surface irrigation	2824	2268	2491	1636	1505	1289	1848
Returns to GW from GW irrigation	0	0	0	0	491	422	457
Returns to GW from D&I withdrawals	14	40	40	40	40	77	77
Sub-total, returns to GW	2838	2308	2531	1676	2036	1788	2382
Natural and induced recharge from river to GW	0	0	0	0	0	0	0
GW flow from other basins	0	0	0	0	0	0	0
Total inputs	8020	7451	7497	6660	6994	6756	7397
Outputs GW irrigation withdrawals, including GW pumping to surface canals	0	0	0	0	641	537	574
GW withdrawals for D&I use	40	110	110	110	110	220	220
Sub-total GW withdrawals	40	110	110	110	751	757	794
Base flow to rivers	7980	7341	7387	6550	6242	5999	6603
GW flow to other basins	0	0	0	0	0	0	0
Direct GW flow to sea	0	0	0	0	0	0	0
Total outputs	8020	7451	7497	6660	6994	6756	7397

DISCUSSION OF RESULTS

Based on the present conditions and average rainfall & the modified model response for sustainable water use conditions is briefly described below.

a) The model indicates that the present average flows are as follows:

SB1: 23308 million cubic meters
SB2: 9234 million cubic meters
Total basin: 32542 million cubic meters

The total flow computed from the model is somewhat less than the observed one, which is 32703 million cubic meters.

b) For the present conditions, the withdrawal required for sustaining agricultural (irrigation) uses, which is all from surface water is 4497 million m^3, and the withdrawals for D&I uses are 1302 million m^3 from surface water & 110 million m^3 from groundwater respectively. Therefore, there are huge potentials in groundwater development in this basin. To sustain these current withdrawals, the surface storage filling and depletion of 7680 million m^3 contributes considerably.

c) The current total natural recharge from rainfall for the basin computed by the model is 5143 million cubic meters, which is about 8.9 percent of average annual rainfall of 57958 million cubic meters. As there is no groundwater use in irrigation in this basin so far, exploiting groundwater for both agricultural and D & I uses inevitably is an priority plan for local Integrated Water Resources Development and Management (IWRDM) so as to achieve the sustainable development and use of water resources. Therefore, in Future III, Future IV and Future V scenarios, 20 percent of groundwater is planed to be abstracted. Moreover, export water, which is 180 million cubic meters in the upstream and 90 million cubic meters in the downstream, together with better water management is also adopted in Future IV to excavate the potentials for water resources use, even though up to now, there is no plan for water export in this area.

Consumptive use of water

For the current condition, the total consumptive use is 23519 million m^3, which comprises 17130 million m^3 of nature sector, 5551 million m^3 of agricultural sector and 838 million m^3 of people sector (D&I). The agricultural use is made up of ET in rain-fed lands (beneficial and inadvertent) as well as irrigated lands, additional ET met from irrigation and reservoir evaporation. The beneficial consumptive use of nature sector in the future five scenarios increased remarkably due to the expansion of forest area (the coverage rate of forest is increased from 36.4% in 1980 to 40% in 2000 and 50% in 2025), but the non-beneficial ET is reduced due to the decrease of waste and fallow land area.

The Scenario Future IV has been attempted to get the maximum practicable expansion, including more groundwater use, better management, export water and more industries. Even though the river flow is reduced slightly from 32542 million cubic meters to 30518 million cubic meters comparing with the BAU Scenario, the total consumptive use is 26610 million cubic meters, closed to the value of BAU Scenario 26537 million cubic meters. Table 10 summarizes the composition of sector consumptive use under different scenarios.

The consumptive use of agricultural sector can be further classified by the status of the land (rain-fed or irrigated). Part of the consumptive use from irrigated land is met either from rainfall or from irrigation waters. Non-beneficial consumption would be from reservoirs, waterlogged areas, or from land without crops in particular season.

Table 10 Consumptive use (evapo-transpiration) by sector (million m^3)

	Past (1980)	Present (2000)	Future I	Future II	Future III	Future IV	Future V

Nature sector beneficial	10126	11128	13908	13910	13910	13910	13126
non beneficial	7102	6003	4075	4241	3936	3850	4435
Subtotal	17228	17130	17983	18151	17846	17760	17561
Rainfed Agriculture sector beneficial	815	872	533	872	832	1280	1209
non-beneficial	17	15	11	15	13	16	16
Subtotal	832	887	544	887	845	1295	1224
D&I (People sector)	535	838	1591	1591	1591	2228	2228
Total for all sectors	**18595**	**18855**	**20118**	**20629**	**20282**	**21283**	**21014**

Surface water

From 1980 to date, surface water is all along the major water source in Qiantang Basin. Particularly for agriculture, 100 percent of irrigation withdrawal is from surface water. For D&I uses, only 5 percent of D&I withdrawal is from surface water in the past and 7 percent in the present conditions. In terms of total water withdrawal for agriculture and D&I, only 0.6 percent is from surface water in the past and 1.8 percent at present. Therefore, the abundant surface water resources here create superior conditions for local socio-economic development.

For the present conditions, as from the model, the withdrawal of surface water was 10 percent of the total inputs, and return flow contributed only 2.5 percent of inputs, the base flow was 7341 million cubic meters, 12.6 percent of the total inputs available in all the months. In the current situation, with average rainfall, total return flows contribute 6.5 percent of total inputs and total withdrawals are equal to 10 percent of the inputs.

In the future scenarios with average rainfall, even with more water consumption for agriculture and D&I, the maximum withdrawals was only 13.5 percent of the total inputs while the maximum return flows constituted 8 percent of the total inputs. Therefore, the sustainability of water resources in this area can be guaranteed.

Groundwater

A little groundwater, which is only 0.2 per cent of total inputs, has been exploited for D&I use in the current situation, return flow, natural & human together, constitutes only 4 percent of the inputs. Therefore, more groundwater use had been adopted in future three scenarios. At the same time, the abundant surface and groundwater resources also provide a scenario for export water. In Future IV scenario, 20 per cent of ground water is planned to be used and totally 270 million cubic meters of water is planned to be exported to other water short basins. But even then, the total withdrawal from groundwater is only 1.3 percent of the total inputs and the return flow would constitute about 3 percent of the inputs. The potentials for groundwater development are very huge in this basin.

The withdrawals of both surface and ground water for different purposes and for different scenarios are shown in Figure 3. Because paddy is the biggest water consumers and still the major crop in this basin, surface water withdrawal for irrigation was reduced remarkably due to the cutting down of rice in the last four scenarios. However, with the rapid growth of population and quick development of industrialization and urbanization, the withdrawal for D&I use is nearly doubled in Future I, II & III scenarios and increased by 160 percent in Future IV & V scenarios. The ratio of irrigation withdrawal to total withdrawal is reduced from 86 percent in the past to 76 percent at present and even to 45 percent in Future IV scenario.

GW pumping & induced recharge

The agriculture and D & I water demand are met both from surface water and ground waters. When the surface water was not available, additional pumping from ground water to the surface canals was required to be done to fulfill the demands. Similarly, because of the heavy ground water withdrawals, the sustainability of the ground water storage, under the average recharge conditions was disturbed. This required the assumption of natural & induced recharge from surface to ground waters. As the abundant surface water resources in this river basin is high enough to meet local water demand as well as the base flow even in dry seasons, GW pumping into canals to meet the deficits in SW is not used. Meanwhile, as no much GW has been developed, natural & induced recharge to balance ground water table also is unnecessary.

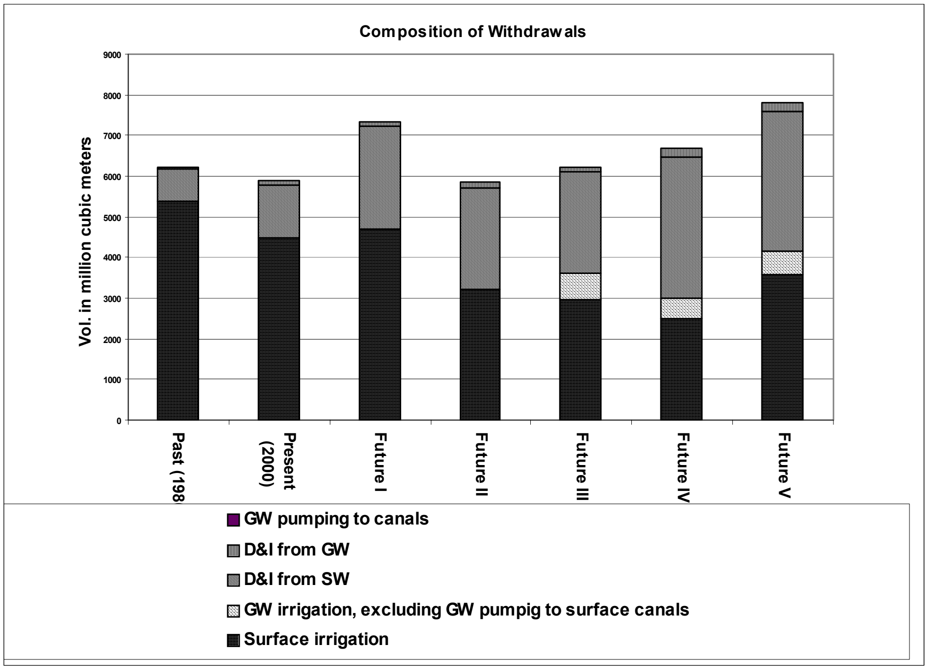


Figure 3. Composition of withdrawals in Qiantang Basin

Water situation indicators

In CPSP Model, four water situation indicators, viz. indicator 1 – total SW withdrawal to total SW inputs, indicator 2 – total returns to SW to total SW inputs, indicator 3 – total GW withdrawals to total GW inputs and indicator 4 – total returns to GW to total GW inputs have been proposed to depict the level of water use (withdrawals) and potential of hazard (due to return flow) to water quality. Values of these indicators for Qiantang Basin are given in Table 10:

Table 10. Water situation indicators

	Past (1980)	**Present (2000)**	**Future I**	**Future II**	**Future III**	**Future IV**	**Future V**
Indicator 1	0.16	0.15	0.19	0.15	0.15	0.16	0.19
Indicator 2	0.04	0.04	0.05	0.05	0.05	0.06	0.06
Indicator 3	0.005	0.01	0.01	0.02	0.11	0.11	0.11
Indicator 4	0.35	0.31	0.34	0.25	0.29	0.26	0.32

It can be seen from the above table that surface water withdrawals is only a small part of the total surface water inputs. Even in the future scenarios, indicator 1 varied from between 0.15 and 0.19, still less than 0.20. In groundwater withdrawal, the ratio varies from 0.005 in the past to 0.01 at present and to 0.11 in the three future scenarios, even with more GW use. However, it should be specially noted that GW return flows is very high in all the studied scenarios, even it was slightly reduced in future II to IV scenarios due to better water management. Therefore, efforts should be made to reduce this indicator to lighten the threat to groundwater quality.

Application of CPSP Hydrological Model in Jiaodong Peninsula Basin,China

Shaoli Wang[1], *Zhanyi Gao*[1], *Jianxin Mu*[1], *Yu Liu*[1]
China Institute of Water Resources and Hydropower Research, Beijing 100044, China

ABSTRACT

CPSP model, a watershed scale hydrological model, was used to simulate the impacts of land and water use on hydrological cycle in Jiaodong peninsula basin, Shandong province, China. The model was calibrated by using past (1980) and present (2000) condition, including the comparison of calculated and observed annual outflow, recharge to groundwater and groundwater fluctuation, and applied to derive responses corresponding to future scenarios using monthly time steps. The results showed that different land types have a large impact on consumptive use, thus influences the total hydrological cycle, especially the land shift between barren land and forestland. The outflow to sea, base flow to surface water and recharge to groundwater decreased from past to present. If not adopting effective management measures, this case would be worse in the future. The groundwater at present has highly been stressed, indicating the unsustainable groundwater balance. With the reduced groundwater use, especially in Yantai where the proportion of groundwater irrigation taking up total irrigation decrease to 0.3 or less, the groundwater would basically reach an approximate balance state. Along with the increase of water use and change of water use pattern, the return flows to input ratio in the surface water system would increase inevitably in the future, signifying more pollution risk for surface water resources, especially downstream water body. Therefore, the related water prevention measures must be adopted to reduce the pollution as soon as possible.

Key words: CPSP model, land use, surface water, groundwater, scenarios

INTRODUCTION

China is the most populous developing country in the world, and its food security is essential to the stability of Chinese as well as global food market. China is also a big irrigation country, where irrigation plays a key role in guaranteeing food production and sustainable agricultural development. However, the water resources per capita in China are less, meanwhile it distributes unevenly both spatially and temporally. How to rationally allocate the limited water resources and guaranteeing the state's food security and the rapid economic development is an important issue in formulating the related water policies.

In recent years, the water demand for food and people sectors are mounting with continued growth of population. The consumptive requirement of the former far outweighs that of the latter. However, with the acceleration of the process of industrialization and cities, the water requirement for industry and domestic (people sector) would increase largely, inevitably occupying the agricultural water uses. The agriculture was confronting more serious water shortage. While claiming water shortages for food and people, little attempt has been done to evaluate basin-wise needs for nature sector in the past. The traditional development pattern, which aims only to pursue a fast economic growth and consume excessively resources and sacrifice environment, has made people' s basic subsisting condition threatened. Therefore, the coordinated development of population, resources and environment has become a major strategy problem commonly concerned by international society.

CPSP model was designed to specifically address future water scenario for food and rural development, water for people as well as for nature, in order to achieve sustainable development and use of the water resources. The model was already applied to Sabarmati and Brahmani basins of India, and acquired a good application results. The objectives of the study were (1) to evaluate the performance of model in simulating the components of hydrological cycle in Jiaodong peninsula basin, Shandong province, China; (2) Using this model to predict the impacts of future scenarios on the basin hydrology, in regard to land and water use; (3) Proposing the related measures highlighted by the study.

OVERVIEW OF CPSP MODEL

CPSP model, a watershed scale hydrologic model, was developed to account for the whole land phase of the hydrologic sector, including the consideration of hydrologic changes due to changes in the land use and agriculture use the impact of sector policies on water supplies and demand. And the model was capable of depicting surface and groundwater balances separately and allowing depiction of interaction between them as well as impacts of storage and depletion through withdrawals. The model was designed to have the characteristics of simplicity, flexibility and capability. On the premise that precipitation constitutes the primary resource, the evapo-transpiration management to increase the flows in rivers/aquifers is considered as a potential development strategy that could be changed through policy intervention.

Water requirements are studied at the basin scale by water use categories. The direct water use by forest and other non-agriculture lands through rain and soil moisture is calculated as actual evapo-transpiration (ET), within the model based on land use statistics, reference ET and values of crop parameter. Options in ET management, such as de-weeding of barren lands to limit its root zone moisture capacity, could be tried in the model. Agricultural water requirements are assessed as potential ET needs of crops that are met through rain and on-field/root zone storage in case of non-irrigated crops. The crop area statistics were used to separate the rain-fed land from irrigated land in the basin and segregate both in agricultural parcels.

The main inputs in the model include hydrological data, crop parameters, land use and land parcel areas, soil moisture capacity for each type of land parcel, irrigation system efficiencies, coefficients for return flow accounts, changes in reservoir storages etc. The model was run on the monthly basis. Maximum 5 sub-basins and 25 land parcels in each sub-basin can be divided and studied by now.

BASIN DESCRIPTION

The Jiaodong peninsula, Yantai and Weihai cities, is in the east part of China, and faces the Huanghai sea and Bohai sea on the east, south and north (called Jiaodong basin below), seeing figure 1. It is a water deficit basin having intensive agriculture and industrial development, and large population density. Based on the previous study dated from 1956 to1999, total water resources volume in Jiaodong basin is 4394 million m^3 per year, in which Yantai City is 2865 million m^3, Weihai city 1529 million m^3. For the current population of 8.929 million, the annual water volume per capita in Jiaodong basin is only 492 m^3, belonging to serious water deficit area. The annual water volume per hectare is 7125m^3, only amounting to one fourth of average value of whole country. The inadequate water resources in Jiaodong basin are a major reason to cause the contradiction between water demand and water supply. The basin has a large irrigation development. The farmland-irrigated area in 2000 is 0.401 million ha, taking up 65% of cultivated area. It is estimated that the farmland-irrigated area in 2025 will reach 0.4603 million ha, increasing 15 percent, whereas the fruit-irrigated area will increase 21 percent in 2025 than in 2000. The major part of the irrigated agriculture is supported by groundwater development at present. The groundwater withdrawal for irrigation accounts for about 67 percent of total irrigation water use□Some areas already occur the overexploitation.

The available cultivated area in Yantai and Weihai cities take up separately 32.3 and 31.6 percent of total land area□and the farmland irrigated area amounts to separately 63.4 and 69.6 percent of the cultivated area. According to previous statistical data, the cultivated area decreases year by year. The main reason is that non-agricultural land and fruit area increase gradually. The gross cropped area also cuts down, especially grain-crops area. However, the cash-crops area goes up□the ratio of grain-crops and cash-crops decreases. The general tendency of cropping intensity variation rises gradually. There are the similar crop patterns in Yantai and Weihai cities. Main crops are wheat, maize, and groundnut. The rotation pattern of winter wheat and summer maize dominates a large part of area in the basin. In the past years, the area for vegetable and melon were on the increase, but the area for grains has been decreasing.

Considering administrative division, similar hydrologic and water use attributes, and available data, two sub-basins in this study are divided and studied; they are Yantai city and Weihai city.

SCENARIOS DESCRIPTION

The various scenarios studied are shown in Table 1. The land use, irrigated area, water use pattern around 1980 year represent the past state, and these terms around 2000 year are the representative of present (2000) condition. The past and present conditions indicate the actual state that ever happened in the basin. The model was run on monthly basis and annual average rainfall conditions for all scenarios studied.

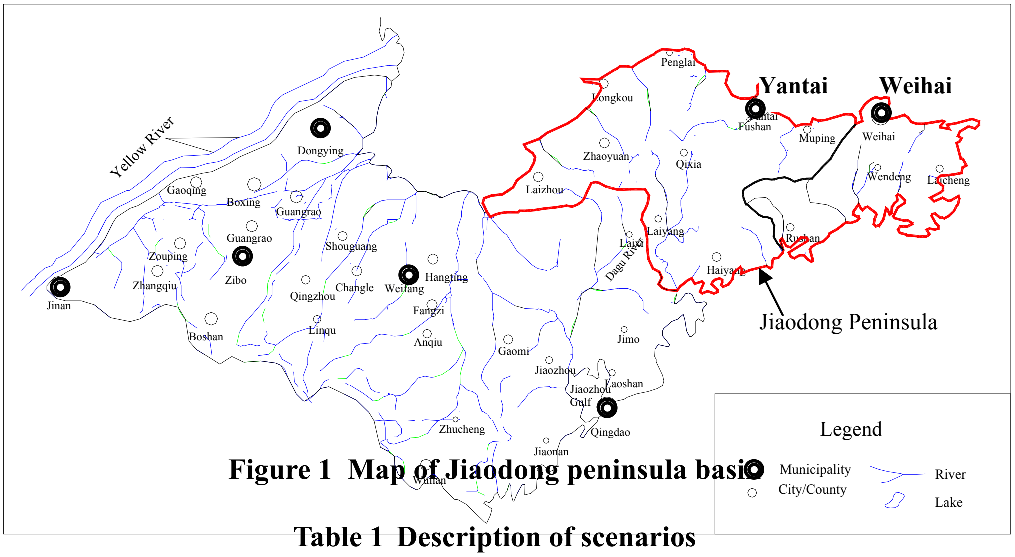


Figure 1 Map of Jiaodong peninsula basin

Table 1 Description of scenarios

Sr. No.	Sr.Studied	Abbreviation	Description
1	Past(1980)	Around 1980	The land uses, irrigated area, water use pattern represent the past conditions around year 1980
2	Present(2000)	Up to date	The land uses, irrigated area, water consumption volume, water use pattern represent 2000's year state.
3	Future I(2025)	B. as U.	Irrigation expansion is based on local planning, the proportion of surface and groundwater irrigation same as at present,the covering rate of forest increases to 40% based on present development speed,and import of about 97 million m3 in Yantai and 50 million m3 water in Weihai.
4	Future II(2025)	B. as U.without expansion of forest	Same as Furture I, but the covering rate of forest area maintains the available level
5	Future III(2025)	Better system mgt and reduced GW use	Same as future II, but the ratio of surface irrigation to total irrigation increased from 0.3 at present to 0.5 in Yantai
6	Future IV(2025)	Same as future III with drip irrigation	Same as future III,but with drip irrigation
7	Future V(2025)	Same as III,soil mgt, import more water and further reduced GW use	Same as future III, soil management in the barren lands,import 300 million m3 water, and further reduced groundwater irrigation ratio from 0.5 to 0.3.

MODEL EVALUATION

The model was calibrated by using past (1980) and present (2000) condition, and applied to derive responses corresponding to future scenarios. Based on the available data, the calibration in two sub-basins was limited to match with the following situation.

1. Comparing the annual outflow with the observed runoff.
2. Comparing the annual total recharge to groundwater computed by the model with the estimations made by local agency.
3. Comparing the groundwater fluctuation within an average year with the observed groundwater fluctuation.
4. Comparing agricultural water use with actual water use observed by local agency.

The approximate comparison for above-mentioned 1, 2 and 3 section between calculated and observed values is shown in table 2. It can be seen from table 2 that the results calculated by model match the observed values well. The outflow and recharge to groundwater at present has a marked reduction than that at past. The main reason might be the change of land uses. The covering rate of forest area in the past and present conditions have a large difference, in which the covering rate of forest area has gone up from 20 percent at past to 30 percent at present. Therefore, the consumption water from nature sector will be increased.

The calculated groundwater storage change within the years was mostly underestimated compared to observed values. Due to missing data, the proportion of groundwater withdrawal given in the model was assumed the same for every month, and equal to the proportion of available yearly groundwater withdrawal. However, the actual proportion of groundwater withdrawal is different between months. During the dry season and high peak of crop water demand, the groundwater withdrawal would contribute a large part of water use. This might be main reason of the difference between calculated and observed groundwater storage change, whereas the rigid matching in the modeling was not tried.

Table 2 Comparison of calculated and observed results for past and present conditions

Condition	Items		Calculated by model	Observed	Difference(%)
Past(1980)	Annual outflow(million m^3)	Yantai	1528	1710	-10.6
		Weihai	1155	1100	5.0
		Total	2683	2810	-4.5
	Annual recharge to groundwater(million m^3)	Yantai	858	895	-4.12
		Weihai	403	399	1.0
		Total	1261	1294	-2.53
	GW flunctuation within the years(mm)	Yantai	362	401.4	-9.81
		Weihai	199	222.9	-10.59
Present(2000)	Annual outflow(million m^3)	Yantai	1136	1165	-2.5
		Weihai	947	912	3.8
		Total	2082	2077	0.3
	Annual recharge to groundwater(million m^3)	Yantai	668	NA	
		Weihai	341	NA	
		Total	1010		
	GW flunctuation within the years(mm)	Yantai	307	375.3	-18.1
		Weihai	169	141.9	18.9

Given reference ET and crop coefficient under the known land uses and crop pattern, the calculated and actual irrigation water use were compared in table 3. It can be seen from table 3 that the calculated irrigation water use was underestimated, especially the larger difference in Yantai occurred. The difference might be that the actual ET be overestimated because the calculation time-step was based on monthly basis, therefore, the effective rainfall might be overestimated. Generally, the calculated results by model are acceptable, and the results show that the selected crop parameters are suitable for local condition.

Through the above calibration, the results shows that the model responses the hydrological features of Jiaodong peninsula well, and can be used for predicting future hydrological cycle and water use situations.

Table 3 Comparison of calculated and actual irrigation water use for past and present condition (million m^3)

Items		Calculated by model	Actual water withdrawal	Difference(%)
Past(1980)	Yantai	767	955	-19.6
	Weihai	237	251	-5.4
	Total	1005	1205	-16.6
Present (2000)	Yantai	687	827	-17.0
	Weihai	232	226	2.6
	Total	919	1054	-12.8

RESULTS AND DISCUSSION

General

Compared to past condition, the outflow to sea and recharge to groundwater at present reduce largely, in which the former has decreased by 22 percent and the latter by 20 percent. The withdrawal of groundwater accounts for 44 percent of total groundwater inputs at past, and 86 percent at present, thus base flow reduce to a great extent.

The model indicates that the total recharge to groundwater at past is 1261 million m^3, which is about 9 percent of average annual rainfall of 13748 million m^3. These values appear reasonable, and match the estimations made by local agency.

The model displays the extreme sensitivity for land use change, especially the shift between barren lands (or other unused lands) and forest area. Under the same irrigation expansion, when the covering rate of forest area is extended from 30 percent to 40 percent, the nature consumption has a marked rise, and the surface water reduces obviously.

In the present condition, the actual irrigated area takes up only 68 percent of command-irrigated area, and the actual water withdrawal for irrigation computed by model is 919 million m^3, which was a little lower than observed values. With the expansion of irrigation in the future scenarios, the command-irrigated area would be 1.16 times as large as that of present condition. The water requirement for agriculture under planned development condition (future I) would reach 1307 million m^3, increasing 42 percent of water withdrawal over the available actual water use. While the proportion of surface irrigation to total irrigation keeps the available level, the water requirement for agriculture, D & I is 1074 million m^3 from surface water and 1440 million m^3 from groundwater. The capacity of surface water supply for future scenarios (2025) will reach 1611 million m^3, completely meeting the demand of surface water withdrawal, but the groundwater withdrawal would far exceed the total inputs. Therefore, various water management measures should be adopted, such as changing water use pattern of surface water and groundwater, improving further the efficiency of water use, import more water, natural &induced recharge from river to groundwater or pumping water from groundwater to river to maintain the river and groundwater balance.

Consumptive use of water

For the current condition, the total consumptive use is 11821 million m^3, including nature sector of 6114 million m^3, agricultural sector of 5429 million m^3 and people sector (D and I) of 277 million m^3. In the total consumptive use, non-beneficial ET is 2291 million m^3 in the nature and 711 million m^3 in the agricultural sectors. The beneficial ET in the nature sector changes obviously with the expansion of forest area or without. Corresponding to 20, 30 and 40 percent of forest covering rate for past, present and scenario future I, the beneficial ET in the nature sector is 2473, 3823 and 4946 million m^3 respectively, non-beneficial ET decreases accordingly. Total ET in the nature sector has increased by 12 percent over the past condition. If the covering rate of forest area continues to expand on the basis of available development speed, total ET in the nature sector would be on the increase and continues to increase by 8 percent in future (2025) over the present condition.

In the agricultural sector, the non-beneficial ET at present takes up 13.2 percent. With the expansion of irrigated area and increase of cropping intensity for future scenarios□the proportion of non-beneficial ET reduces to 10—11.3 percent. To reduce the non-beneficial ET in the agricultural sector, the soil and water management in the fallow lands can lead to an improvement ET, such as scenario V including better soil management in the barren land, non beneficial consumption from irrigated land would reduce to10.1 percent.

Compared to present condition, the command-irrigated area in the future scenarios increase by 16 percent. Owing to the adoption of water-saving measures, the increase of irrigation water use is not so large that the agricultural consumptive use rises less, especially for future V with the increase of 2 percent. Table 4 summaries the composition of sector's consumptive use under different scenarios.

Table 4 Consumptive use (evapo-transpiration) by sectors (Million m^3)

	Past(1980)	Present(2000)	Future I (2025), B.as U.	Future II, B as U without expansion of forest	Future III, with better system mgt and reduced GW use	Future IV, same as future III,drip irrigation	Future V, same as III, more drip and soil mgt,import
Nature sector							
Beneficial	2473	3823	4946	3823	3823	3823	3823
Non beneficial	2986	2291	1656	2416	2416	2416	2416
Agriculture sector							
Beneficial	4690	4718	4985	4985	4977	4975	4990
Non beneficial	671	711	637	637	637	637	559
D&I (People sector)	136	277	500	500	500	500	500
Total all sectors	10956	11821	12723	12361	12353	12352	12289

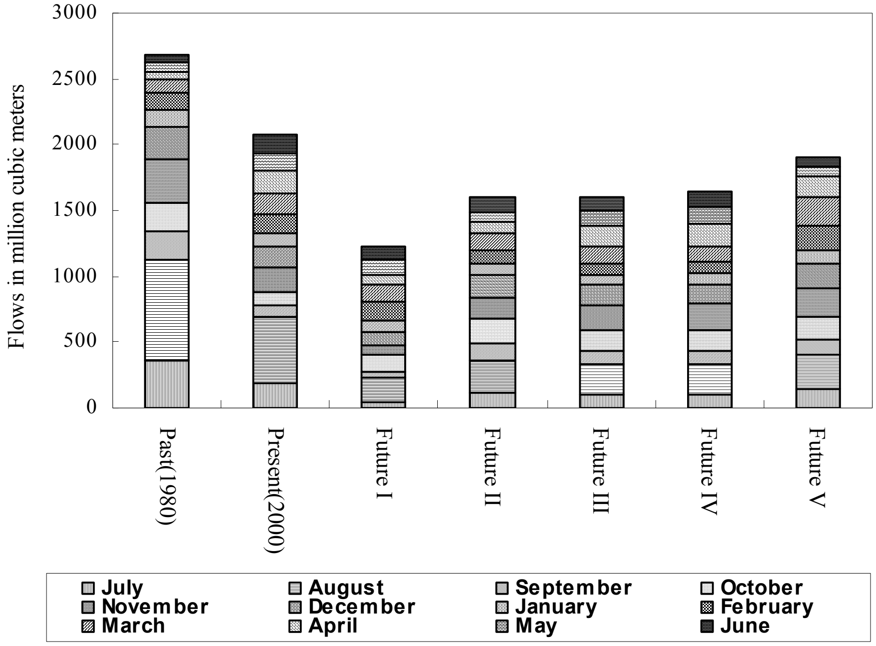
Surface water

The withdrawal of surface water at past and present was the similar and equal to 22 percent of total inputs, but the return flows contribute 6 percent of total inputs at past and 10 percent at present. Thus more risk for pollution of downstream water was caused at present than at past. Also, the base flow availability reduced significantly at present.

In the future scenarios, the water requirement in the command-irrigated area is far larger than available actual irrigation water use, and the predicted water use for D&I go up much too. The withdrawal of surface water reaches 33—41 percent of total inputs. With reduced groundwater use in Yantai, the withdrawal to input ratio for scenario future III and IV reaches about 41 and 40 percent respectively, and return flows to input ratio approaches all 19 percent. With further reduced groundwater withdrawal and more import water, scenarios future V have 41 percent of surface withdrawal to total inputs, and the return flows to input ratio is a little lower than that of other future scenarios.

In all future scenarios, the base flow and river outflow are affected by the pattern of development, and reaches the smallest for scenario future I. The total river flows (after providing the natural & induced recharge from river to ground water) and its monthly distribution are shown in Figure 2. From scenario future I to future V, the total river flows increased gradually. The outflow to sea for scenario future V approaches the available level and only 4 percent lower than that of present condition.

Figure 2 Monthly river flows in Jiaodong basin



Groundwater

The extensive groundwater use in the basin has been practiced. In the past condition (1980), the withdrawal of groundwater constitutes only 44 percent of the inputs, whereas the return flow is 32 percent of the inputs. In the present condition, the withdrawal of groundwater accounts for 86 percent of the inputs, indicating the unsustainable groundwater balance. For scenario future I with business as usual, the withdrawal of groundwater contributes still 87 percent of the inputs even though 600 million m^3 of induced recharge from river to groundwater, but the return flows to input ratio decreases.

In order to maintain the groundwater balance, the proportion of groundwater withdrawal should be reduced, especially for Yantai. When the proportion of surface irrigation to total irrigation in Yantai for scenario future III increased to 50 percent from available 30 percent, the withdrawal maintains the similar ratio compared to future II but with 300 million m^3 of induced recharge. With more drip irrigation (future IV), further reduced groundwater use (future V), the withdrawals would constitute 78 and 76 percent of the inputs respectively, whereas the induced recharge for future V decreased to 100 million m^3, the return flow to input ratio increases a little, and future V reaches an approximate balance state. The withdrawals of both surface water and groundwater for different scenarios are shown in Figure 3.

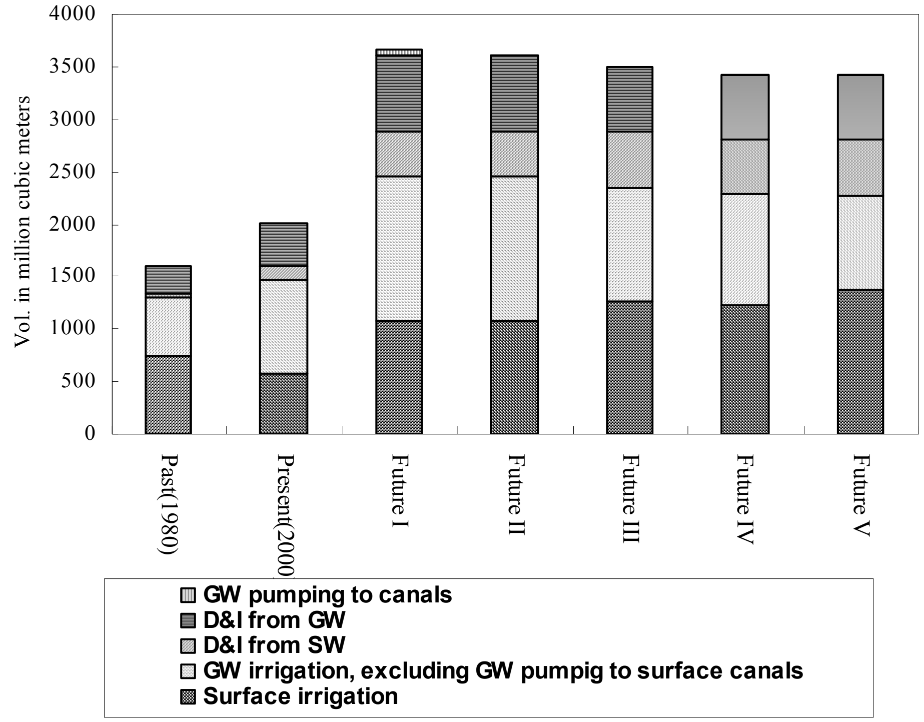


Figure 3 Composition of withdrawals in Jiaodong basin

GW pumping & induced recharge

The withdrawals from surface and ground water would be met from the available surface and groundwater waters. When the surface water was not available, additional pumping from ground water to the surface canals was required to fulfill the surface water demands. Similarly, due to heavy groundwater withdrawals, the sustainability of the groundwater storage under the average recharge conditions would be disturbed, and the assumption of natural and induced recharge from surface to groundwater would be required. The demands for groundwater pumping into canals and natural & induced recharge for all scenarios are given in table 5. The groundwater pumping to canals is often at the time when the river flow is low and the water requirement for crops is high. Whereas the natural & induced recharge from river to GW is mostly in the high flow months. Obviously, if maintaining available 30 percent proportion of surface irrigation to total irrigation, more natural & induced recharge from river to groundwater for scenarios future I and II was needed because the groundwater was overexploited. While the proportion of surface irrigation to total irrigation in Yantai increases to 50 percent such as scenario future III and IV, the natural & induced recharge could be reduced, but the groundwater withdrawal approaches or exceeds the exploitation rate, and the groundwater balance would confront crisis. If the proportion of surface irrigation to total irrigation in Yantai further increases to 70 percent and import more water, the groundwater withdrawal to input ratio maintains the similar level and the natural & induced recharge could be reduced, the groundwater could maintain an approximate balance for a long time. Given surface storage filling and depletion for all future scenarios, the groundwater pumping to surface canals for meeting shortages in surface irrigation would be zero except future I in which 58 million m^3 water is needed to meet the filling of surface storage. If the other water sources such as saline water, sewage reuse and seawater use could be developed to meet the shortages; the surface water and groundwater situation could be improved further.

Table 5 Requirements of groundwater pumping into canals and Natural and/or induced recharge from river to groundwater for all scenarios (Million m^3)

Description	Past	Present	Future I	Future II	Future III	Future IV	Future V
Natural & induced recharge from river to GW for balancing the GW	0	0	600	600	300	300	100
GW pumping to surface canals for meeting shortages in surface irrigation	0	0	58	0	0	0	0

Water situation indicators

The four water situation indicators were proposed to depict the level of water use (withdrawals) and potential of hazard (due to return flow) to water quality. Table 6 presents the values of these indicators. Indicator 1 and 2 represent respectively the proportion of surface withdrawal and return flows taking up total surface inputs. Indicators 3 and 4 represent respectively the proportion of groundwater withdrawal and return flows taking up total groundwater inputs. It can be seen that the groundwater withdrawal in Jiaodong peninsula basin was highly stressed than past condition, and groundwater quality was under moderate threat. With the increase of surface water use, the return flows to input ratio would increase largely compared to past and present conditions, indicating more risk of pollution for surface water resources, especially downstream water. Therefore, the related water prevention measures must be adopted to lighten the pollution pressure as soon as possible along with the change of water use pattern.

Table 6 Water situation indicators

	Past	Present	Future I	Future II	Future III	Future IV	Future V
Indicator 1	0.217	0.218	0.358	0.327	0.398	0.386	0.406
Indicator 2	0.062	0.103	0.218	0.189	0.193	0.191	0.182
Indicator 3	0.439	0.858	0.867	0.781	0.788	0.780	0.761
Indicator 4	0.324	0.336	0.306	0.288	0.300	0.292	0.340

CONCLUSIONS

The model outputs show that the outflow to sea and recharge to groundwater were on the decrease from past to present, in which the annual outflow to sea reaches 2683 million m^3 in the past condition, and 2082 million m^3 in the present condition, the annual total recharge to groundwater is 1261 million m^3 in the past condition, and 1010 million m^3 in the present condition that match the observed results made by local agency. For scenario future I with business as usual, the river outflow reaches the smallest in all scenarios. Through adopting different measures, from scenario future I to future V, the total river flows increased gradually. The outflow to sea for scenario future V approaches the available level with 4 percent lower than that of present condition.

The different land types have a large impact on consumptive use, thus influences the total hydrological cycle, especially the land shift between barren land and forestland. Corresponding to 20, 30 and 40 percent covering rate of forest area at past, present and future scenario I, the consumptive use from the nature sector would be respectively 5459, 6114 and 6601 million m^3.

Total ET in the nature sector at present has increased by 12 percent over the past condition and increased by 8 in future I (2025) over the present condition. Therefore, the expansion of the forest area should be in consistent with local water resources and agricultural development.

The base flow from groundwater to river is decreasing from 592 million m^3 per year at past to 292 million m^3 per year at present, this indicates a decreasing groundwater storage, thus signifying the crisis of the groundwater deterioration. The groundwater withdrawal has higher stress than past condition. In order to sustain the groundwater balance, the groundwater withdrawal should be reduced, especially for Yantai. While the proportion of surface irrigation to total irrigation increases to 70 percent in Yantai and better water and soil management was adopted, the groundwater withdrawal for future V would decrease to 901 million m^3.

With the increase of water use, the ratio of return flows taking up input would increase inevitably in the future, indicating more pollution risk for surface water resources, especially downstream water body. Therefore, the related water prevention measures must be adopted to reduce the pollution as soon as possible along with the change of water use pattern.

With the increase of Industry and domestic water use, the agriculture would confront more serious water shortage. It is necessary to implement the optimal allocation and combined regulation of multi-water sources, increase the water reuse and water use efficiency, build the complete water engineering to increase the guarantee rate of water supply and enhance the prevention of water resources.