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Country Policy Support Program (CPSP)

PODIUMSIM

CPSP Report 10

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International Commission on Irrigation and Drainage

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PODIUMSIM

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PODIUMSIM

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PODIUMSIM

1. Background

PODIUM, the Policy Dialogue Model, designed in Microsoft Excel environment, is a user friendly interactive scenario generating tool for scientists and policy makers (www.iwmi.org). Having published its first major report in assessing the future water supply and demand of world's major countries (Seckler et al 1998), the International Water Management Institute (IWMI), has refined the data and methodology of the assessment and developed a new model PODIUM. It explores the technical, social and economic aspects of alternative scenarios of future water demand and supply at country level.

The participants in many consultations and workshops viewed the PODIUM as a useful scenario generating tool. The scientist and the policy makers of various countries used the PODIUM model for generating alternative scenarios of water supply and demand in their national consultations leading to the 2nd World Water Forum in Hague. IWMI has used PODIUM for developing three scenarios for the World Water Council's Vision program (IWMI 200, Rijsberman 2000). However, some limitations, as highlighted in the consultations, exist in the first version of the PODIUM model. The model considers only one crop- cereals- for food and water demand assessment. And the model does not have the capacity to estimate food demand supply and water demand for individual crops, even within the cereals category. Further, the model also does not capture the spatial variations of water supply and demand, especially for large countries such as India and China.

The PODIUM, upgraded through the Country Policy Support Program (CPSP) of the International Commission and Irrigation and Drainage (ICID), addresses the limitations of the model and the concerns of various users. The Country Policy Support Program of the ICID contributes to identifying effective options for water management to the achievement of an acceptable food security level and sustainable rural development, primarily in China and India. As part of the CPSP, the IWMI and the International Food Policy Research Institute (IFPRI) were to

1. Improve the PODIUM model to handle country specific issues at sub-national level and
2. Integrate PODIUM and IMPACT to better address the hydrologic and economic issues for developing scenarios.

The upgraded PODIUM model is PODIUMSIM and this report provides the details of upgrading PODIUM model.

2. PODIUMSIM for CPSP

2.1 PODIUM to PODIUMSIM – Upgrades

The PODIUMSim retains the four major components of the PODIUM: Consumption, Production, Water Demand and Water supply. However, substantial improvements exist both at spatial and temporal scale within individual components. The table 1 shows the differences-the temporal and spatial scales at which the scenarios that are developed for different components. A notable improvement in PODIUMSIM is the introduction of sub-national units to capture the spatial variation of water supply and demand. At temporal scale, the irrigation water needs are now assessed at monthly time periods and then aggregates to obtain seasonal and annual agriculture water requirements.

Table 1. Spatial and temporal scale improvements of different components

Component	PODIUM		PODIUMSIM	
	Spatial scale	Temporal scale	Spatial scale	Temporal scale
Consumption	National	Annual	National	Annual
Production	National	Seasonal	River basin	Seasonal
Water Demand				
Irrigation	National	Seasonal	River Basin	Monthly
Domestic	National	Annual	River Basin	Annual
Industrial	National	Annual	River basin	Annual
Environment	-	-	River basin	Annual/Monthly
Water Supply	National	Annual	River Basin	Annual

2.2 Crop consumption estimation

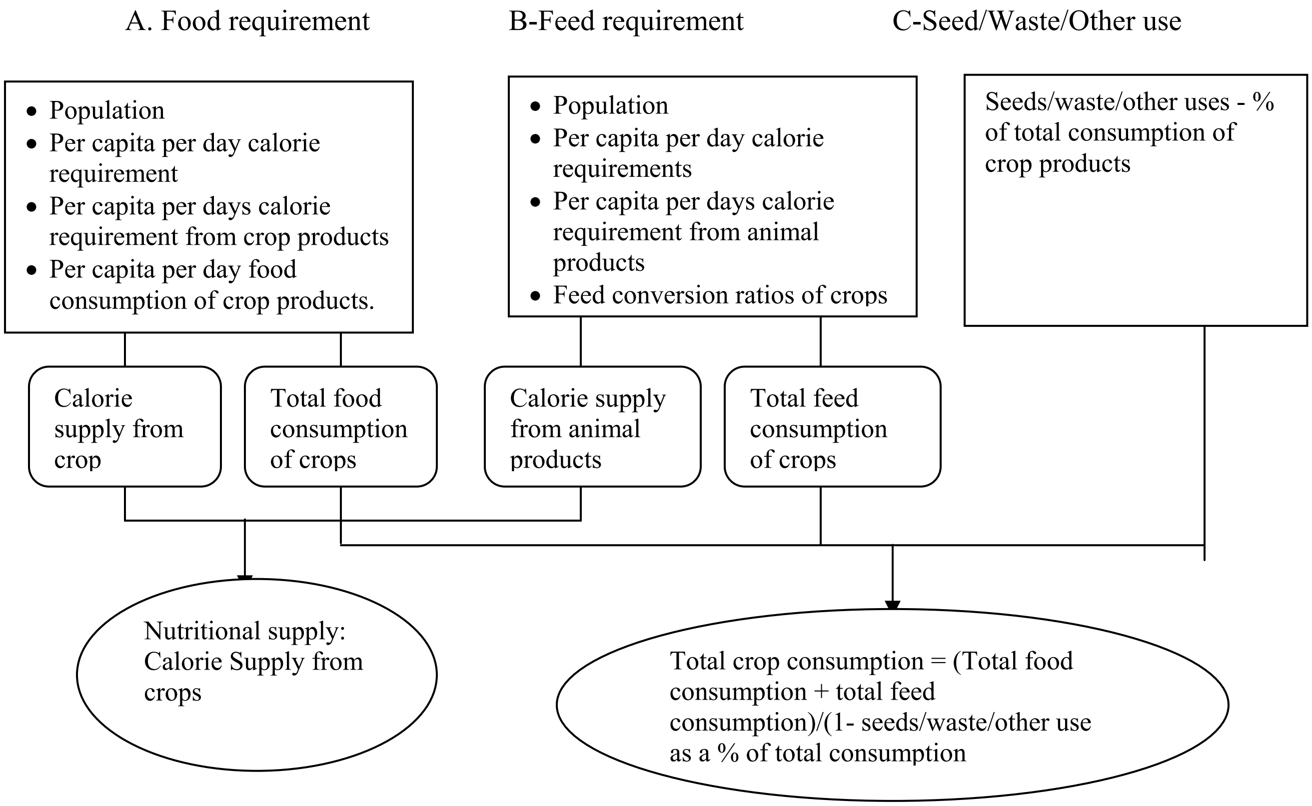
The major improvement in the consumption component is that details of consumption patterns of 11 crop categories are now available for both rural and urban sectors (Table 2)

Table 2. Drivers of the consumption component

Drivers	PODIUM	PODIUMSIM
Population	National	National (Rural & Urban)
Total calorie supply/person/day	National	National (Rural & Urban)
% Calorie supply from Grains	National	National (Rural & Urban)
% calorie supply from oil crops	-	National (Rural & Urban)
% calorie supply from fruits and vegetables	-	National (Rural & Urban)
% calorie supply from animal products	National	National (Rural & Urban)
Per capita food consumption of	Cereals	10 crop categories (rice, wheat, maize, other cereals, pulses, oil crops, roots and tubers, vegetables, fruits, sugar)
Feed conversion factors (i.e., kg of feed for a unit a animal product)	Cereals	10 crop categories
Seeds/Waste/Other uses	Cereals	10 crops (9 crop categories and cotton)

This component first estimates the food requirement, the feed requirements and the seeds/waste/other uses separately for 10 crop categories and then aggregate to obtain grain, non-grain and total crop requirement. The figure 1 shows the flow diagram of estimation of crop requirements for a given level of nutritional requirements.

Figure 1. Flow diagram of consumption component



Food requirement: The major drivers of food requirement estimation are

- population growth
- per person daily calorie requirement growth
- composition of daily calorie supply changes, i.e., changes in the daily calorie supply from grains, oil crops, fruits and vegetables and other crop products as a percent of total calorie supply and
- the changes in daily consumption of crop products such as rice, wheat, maize, other cereals, pulses, oil crops, roots and tubers, vegetables, sugar, fruits.

The growth or changes of the drivers satisfies the constraint that the absolute difference of calorie requirement and calorie supply, i.e., |calorie requirement – calorie supply from crop consumption|, of crop categories of grains, oil crops, fruits/vegetables and other crops should be less than 5 kcal. The food requirement of i^{th} crop or crop category is estimated as

Food consumption of i^{th} crop = Total population × Consumption/pc/day of i^{th} crop × 365

Feed requirement: The major drivers of feed requirement estimation are

- population growth
- total calorie requirement growth,
- growth in per person calorie supply from animal products in the total and
- the changes in feed conversion ratios, i.e., the quantity of different crop products for supplying the required calorie supply from animal crop products.

The feed consumption of i^{th} crop or crop category is estimates as

Feed consumption of i^{th} crop = Total population × animal products calorie supply/pc/day ×365 × feed conversion ratio of crop i

Seeds/Waste/Other uses: The quantity of seeds/waste and other uses of crop as a percentage of total crop consumption is a driver of estimating total crop requirement.

Total requirement of crop i:

Total consumption of crop i = (Food consumption of crop i+ Feed consumption of crop i) / (1- (seeds/waste/other use of crop i as % of total consumption)).
In addition to the food crops, we estimate the annual requirement of cotton (lint equivalent).

Grain, non-grain and all crop requirements: The total crop requirements of grains, non-grains and all crops of the scenario year are shown as the aggregate value of crop products based on base year export prices. The base year export prices are used only as a means of aggregating the quantity of different crop products. Let R_{ti} and P_{0i} are the total quantity of consumption of crop i in year t and the base year unit export prices of crop i. Then

Grain crop requirement $= \sum R_{ti} \times P_{0i}$, $i \in$ (Rice-milled equivalent, wheat, maize, other cereals, pulses)

Non-grain crop requirement $= \sum R_{ti} \times P_{0i}$, $i \in$ (oil crops, roots and tubers, vegetables, sugar, fruits, cotton)

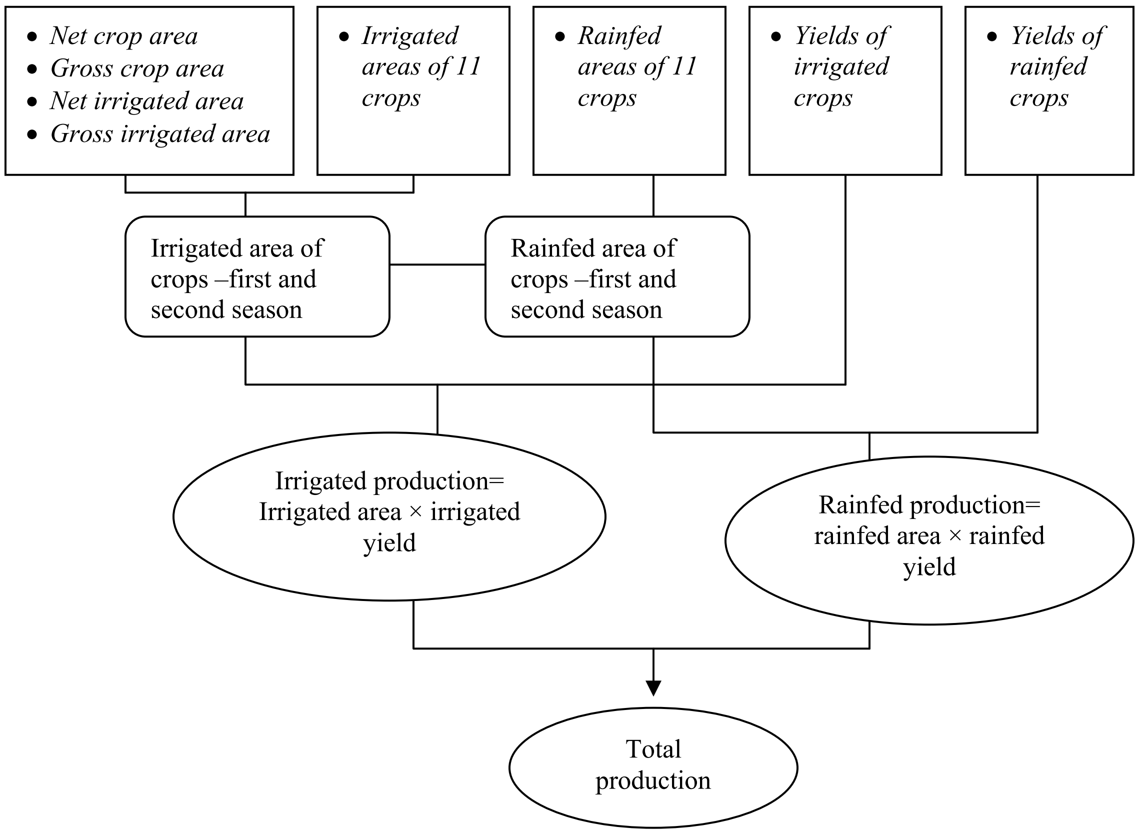
2.3 Crop production estimation

The major improvement of this component of PODIUMSIM is its capacity to capture the spatial variability of production potentials of several crop categories. The model estimates crop production at river basin level for 11 crop categories in both irrigation and rain fed condition. Table 3 shows the major drivers.

Table 3. Major drivers of crop production component

Drivers	PODIUM	PODIUMSIM
Net irrigated area	National	River basin
Gross irrigated area	National	River basin
Irrigated crop area	Cereals at national level for two season	11 crop categories at river basin level for two seasons
Rainfed crop area	Cereals at national level annually	11 crop categories at river basin level for two seasons
Irrigated crop yield	Cereals at national level for two season	11 crop categories at river basin level for two seasons
Rainfed crop yields	Cereals at national level annually	11 crop categories at river basin level for two seasons

Figure 2. Flow chart of crop production estimation



First, the growth of net and gross crop area and net and gross irrigated are specified. This gives the changes of total crop areas under irrigated and rainfed conditions for two seasons and cropping intensities.

Overall cropping intensity = gross crop area/ net crop area, and
Irrigated cropping intensity = gross irrigated area/ net irrigated area.

Second the seasonal irrigated cropping patterns, i.e., the irrigated crops areas are specified. The changes in irrigated crop areas in the two seasons satisfy the following constraints:

First-season total irrigated crop area ≤ net irrigated area
Change in first season irrigated crop area ≥ change in net irrigated area
Change second season irrigated area = change in gross irrigated area – change in first season irrigated area.

Third, the seasonal rainfed cropping patterns, i.e., rainfed crop areas, are specified. Changes in rainfed crop areas satisfy the following constraints.

First-season total rainfed crop area ≤ net crop area - net irrigated area
Change in first season rainfed crop area ≥ changes in (net crop area – net irrigated area)
Change in second season rainfed area = changes in (gross crop area – gross irrigated area)-changes in first season rainfed crop area

Fourth, the growth of irrigated and rainfed crop yields are specified. The crop production of i^{th} crop is

$Total\ production\text{-}crop_i = \sum area\text{-}crop_{ij} \times yield\text{-}crop_{ij}$ $j \in$(first season, second season).

2.4 Agriculture water requirement estimation

PODIUMSIM has substantial improvements in irrigation water requirement estimation. It now captures the variation of crop water requirements temporally by monthly estimations and spatially by river basins level estimations. Table 4 shows the key drivers and the upgrades of PODIUMSIM over the PODIUM model.

Table 4. Drivers of crop water requirement estimation

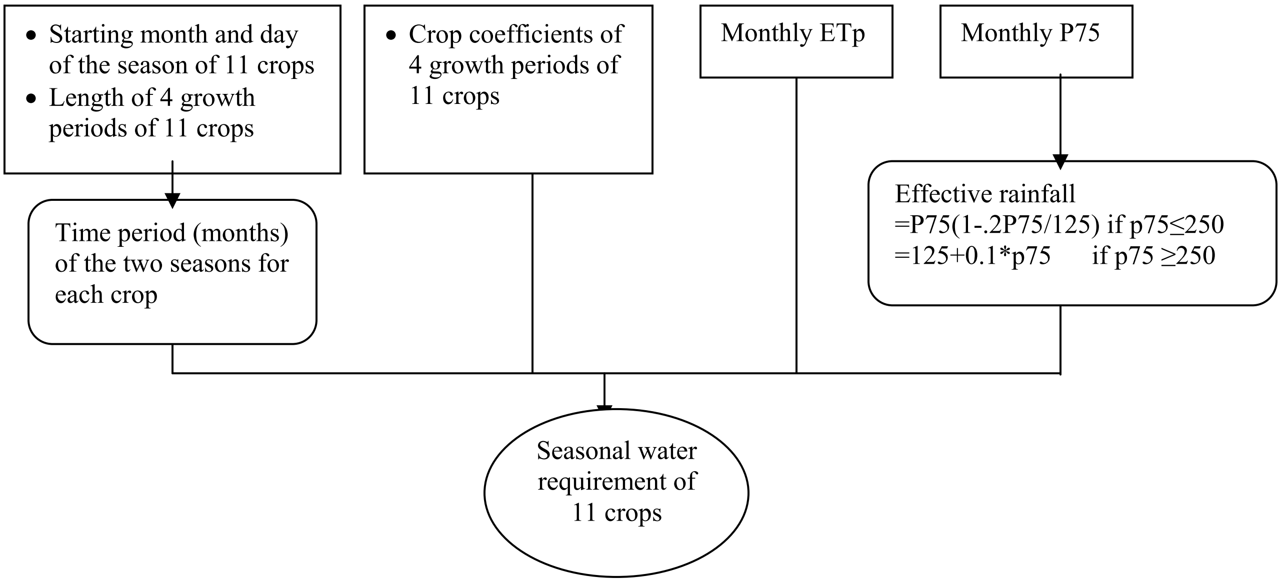
Drivers	PODIUM	PODIUMSIM
P75 (75 percent exceedence probability rainfall)	Two seasons at national level	Monthly at river basin level
ETp (potential evapo-transpiration)	Two seasons at national level	Monthly at river basin level
Crop calendar – Starting date of the season	Starting month of two seasons for cereals at national level	Starting month and day of two seasons for 11 crop categories at river basin level
Length (number of days) of crop growth periods	Number of months in two seasons at national level	Number of days in four growth periods for each seasons at river basin level
Crop coefficients	For cereals in two seasons at national level	For 11 crop categories, in four crop growth periods in each season at river basin level
Crop area	Seasonal irrigated area at national level	Irrigated area of 11 crops in two seasons at river basin level
Groundwater irrigated area	-	Seasonally at river basin level
Percolation requirement for paddy	Seasonal at national level	Seasonal at river basin level
Project efficiency-surface irrigation	Seasonally at national level	Seasonally at river basin level
Project efficiency-Ground water irrigation	-	Seasonally at river basin level

Crop Water Requirement: First the model estimates crop water requirement for each crop (Figure 3). First it determines the time (months) of the growth periods using the starting date (month and day) of the season and the length of the growth periods and also the effective rainfall for each month using P75. Next it estimates the crop water requirement for each growth period using effective rainfall, Etp and crop coefficients. The seasonal crop water requirement of each crop is given by

$$Water\ req\ of\ Crop^{l} = \sum_{i \in groth\ periods} \sum_{j_i \in months} \max\left[\left(Effe.\,rain_{ij_i} - Crop\ coeff^{\,l}_{ij_i} \times ETp_{ij_i}\right), 0\right] \times \frac{d^{\,l}_{ij_i}}{n^{\,l}_{ij_i}}$$

Where; k $\in$ 11 crops (rice, wheat, maize, other cereals, pulses, oil crops, vegetables, fruits, sugar, cotton), i$\in$ four growth periods (initial, development, middle and late) , $j_i \in j^{th}$ months in i^{th} crop growth period), $d^{\,l}_{ij_i}$ = number of days of j^{th} months in i^{th} crop growth period of crop k, and n_{j_i} =number of days of j_i^{th} month.

Figure 3. Flow chart of estimating crop water requirement



Irrigation water requirement: Next the model estimates irrigation water requirement of the river basin. Let

IA_{ij} – irrigated area of i^{th} crop in j^{th} season
CWR_{ij}- crop water requirement of i^{th} crop in j^{th} season
PER_j – Percolation requirement for paddy in j^{th} season
$GWIA_j$ – Groundwater irrigated area as a percent of total irrigated area in j^{th} season
SEP_j - Surface project irrigation efficiency paddy in j^{th} season
SEOCj - Surface project irrigation efficiency other crops in j^{th} season
GE_j - Ground water project irrigation efficiency in j^{th} season
PERj - Percolation requirement for paddy in j^{th} season

Then the annual irrigation requirement is

$$Irrigation\ water\ requirement = \sum_{j=1}^{2}(1-GWIA_j)\left(\frac{CWR_j^{paddy}+PER_j}{SEP_j}+\frac{\sum_{i\in other\ crops} CWR_{ij}}{SEOC_j}\right) + \sum_{j=1}^{2} GWIA_j\left(\frac{CWR_j^{paddy}+PER_j+\sum_{i\in other\ crops} CWR_{ij}}{GE_j}\right)$$

2.5 Domestic and industrial water requirement estimation

The domestic water requirement includes water requirements for humans and livestock. The drivers of estimating domestic human and livestock water requirements and industrial water requirements are shown in Table 5.

Table 5. Drivers of Domestic and Industrial water requirement assessment

Drivers	PODIUM	PODIUMSIM
Urban and Rural population	National level	River basins
Daily per person withdrawals for urban and rural sectors	National level	River basins
Percent urban and rural population with pipe water supply	National level	River basins
# of animals (cattle, goats, pigs and others)	-	River basins
Daily per animal water requirement	-	River basins
Total industrial water requirements	National	River basins

The domestic water requirement humans and livestock are estimated by

$$Domstic\ water\ requirement\ \ for\ humans = \sum_{i=Urban,Rural} \begin{pmatrix} Population_i \times \%pop.\ with\ pipe\ water\ \mathrm{sup}\ ply_i \times \\ Per\ capita\ daily\ requirement_i \times 365 \end{pmatrix}$$

$$Livestock\ water\ requirement = \sum_{i \in (cattles, goats, pigs)} \begin{pmatrix} Number\ of\ \ animal \times Daily\ water\ requirement \\ per\ animal \times 365 \end{pmatrix}$$

The growth of total industrial water requirement is taken as a driver in future industrial water requirement assessment.

2.6 Environmental flow requirement estimation

The environmental flow requirement module, a new component in the PODIUMSIM, incorporates scenarios of annual river flow requirements that need to be met from the potentially utilizable water resources. It operates at river basin level and has two options: it can either directly enter the annual environmental flow requirements or can estimate from the monthly environmental flow requirements. The drivers of this component are given in Table 6.

Table 6. Drivers of environmental flow requirement assessment

Drivers	PODIUMSIM
Annual river flow requirement	Annual values at river basin level
Monthly renewable surface water resources	Monthly at river basin level
Potentially utilizable water resources	Monthly at river basin level
% of minimum flow requirement to be met from potentially utilizable water resources	Monthly at river basin level

In the case of estimation from monthly flows, first we observe that for each month all or part of the minimum flow requirement can be met from the un-utilizable part of the renewable surface water resources (RSWR). Second, all or part of the minimum flow requirement that cannot be met from un-utilizable RSWR has to be met by the potentially utilizable surface water resources (PUSWR). The model keeps this portion of PUWR as a driver for determining environmental flow requirement scenarios. Let

MFR_i – Minimum flow requirement of i^{th} month
$RSWR_i$ - Renewable surface water resources of i^{th} month
$PUWR_i$ – Potentially utilizable water resources of i^{th} month
$PCTMFR_i$ – Percent of minimum flow requirement to be met from $PUWR_i$

The environmental flow requirement is estimated as

$$Environmental\ \ flow\ requirement = \sum_{i=1}^{12} Max\left(RSWR_i - PUWR_i - MFR_i, 0\right) \times \%MFR_i$$

The PODIUMSIM model consider that the estimated environmental water requirement has to be deducted from the potentially utilizable water supply for estimating potentially available water supply for other sectors of water use.

2.7 Utilizable *water resources estimation*

This component estimates the potentially available water resources for agriculture, domestic and industrial sectors of water use. Table 7 shows the drivers and improvements in the PODIUMSIM model.

Table 7. Drivers of potentially utilizable water resources assessment

Drivers	**PODIUM**	**PODIUMSIM**
Potentially utilizable surface water resources	Annually at country level	Annually at river basin level
Potentially utilizable groundwater resources	Annually at country level	Annually at river basin level
Water transfers in	Annually at country level	Annually at river basin level
Water transfers out	Annually at country level	Annually at river basin level
Environmental water requirement	-	Annually at river basin level

The potentially available water resources is

$$\begin{aligned} Available\ water\ resources = {} & Potentially\ Utilizable\ surface\ and\ ground\ water\ resources \\ & + Water\ transfers\ in - water\ transfers\ out + \\ & + Environmental\ water\ requirement \end{aligned}$$

2.8 Accounting of utilizable water resources

The PODIMSIM model estimate water accounting for potentially utilizable water resources of river basins. Part of the potentially utilizable water resources is developed and used in different sectors of water use. Of the water diversions to agriculture, domestic and industrial sectors, the model estimates

1. Process evaporation (evapotranspiration in irrigation and consumptive use in domestic and industrial sectors)
2. Balance flows, i.e., the difference between withdrawals and process evaporation
3. Return flows to surface water supply
4. Recharge to ground water supply
5. Non-process evaporation, i.e., flows to swamps in irrigation,
6. Un-utilizable flows to the sea or a sink and
7. Utilizable flows to sea from the surface return flows and groundwater recharge.

The total process evaporation of the three sectors is given by

$$Total\ \ process\ evaporation = \begin{cases} \sum_{i \in allcrops} (water\ req\ crop_i \times area\ crop_i) + \\ Domestic\ water\ withdrawals \times consumptive\ use\ \ factor^{Dom} + \\ Industrial\ water\ withdrawals \times consumptive\ use\ \ factor^{Ind} \end{cases}$$

i. Balance flow (BF) of each sector is defined as the difference between water withdrawals and process evapotranspiration. The return flows to surface and recharge to groundwater in each sector are estimated as

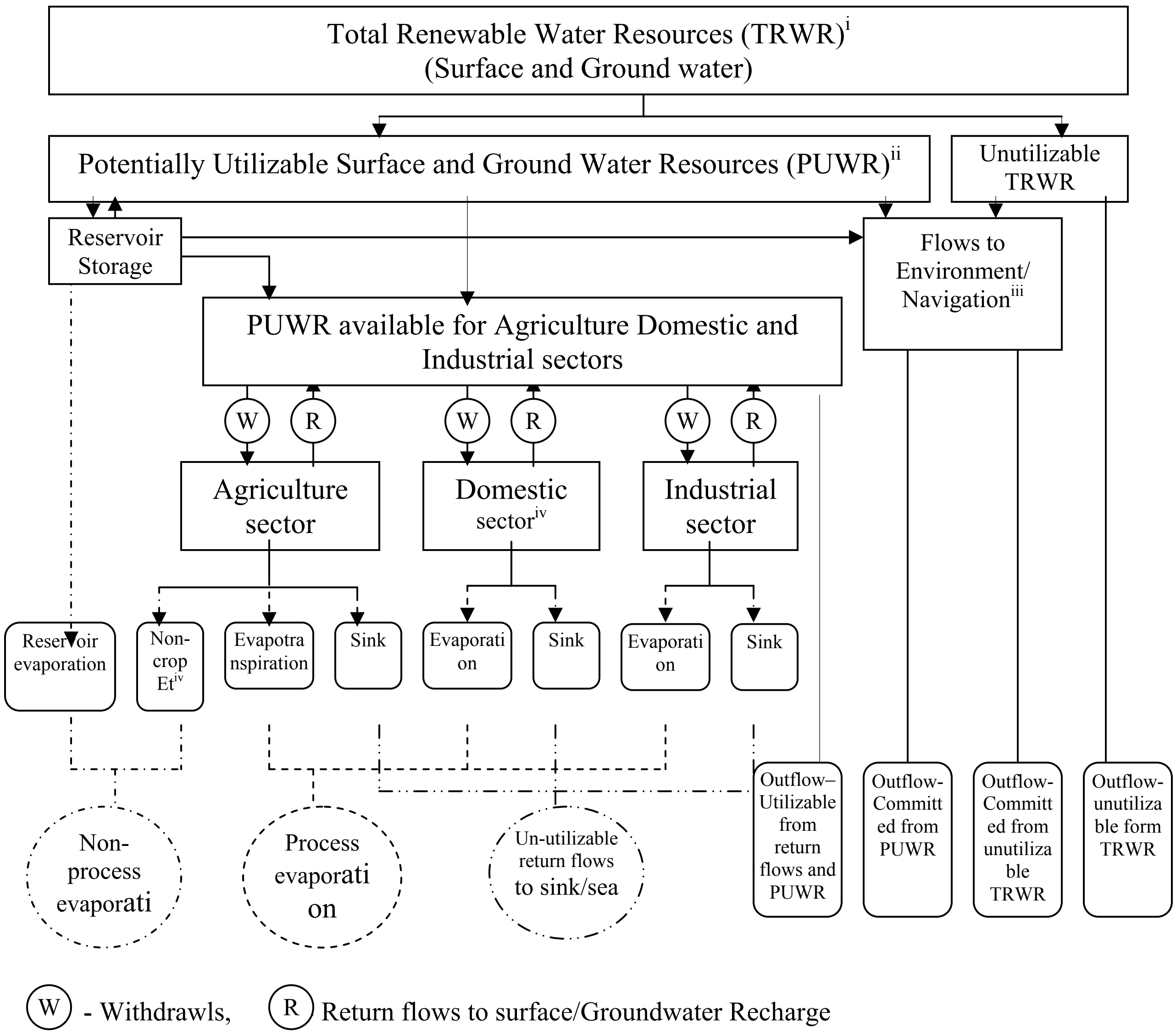
$$\mathrm{Re}\,turn\ \ flows\ to\ surface\ water = \begin{cases} Balanceflow^{irri} \times \%\ balance\ \ flows\ to\ surafce^{irri} + \\ Balanceflow^{Dom} \times \%\ balance\ \ flows\ to\ surafce^{Dom} + \\ Balanceflow^{Ind} \times \%\ balance\ \ flows\ to\ surafce^{Ind} \end{cases}$$

$$Ground\ \ water\ rech\,\mathrm{arg}\,e = \begin{cases} Balanceflow^{irri} \times \%\ balanceflow\ rech\,\mathrm{arg}\,e\ to\ groundwater^{irri} + \\ Balanceflow^{Dom} \times \%\ balanceflow\ rech\,\mathrm{arg}\,e\ to\ groundwater^{Dom} + \\ Balanceflow^{Ind} \times \%\ balanceflow\ rech\,\mathrm{arg}\,e\ to\ groundwater^{Ind} \end{cases}$$

The non-process evaporation is estimated as

$$Total\ non\ process\ evaporation = \begin{cases} Balance\ \ flow\ of\ \ irrigation \times \%BF\ to\ swamps + \\ \mathrm{Re}\,servoir\ storage\ capacity \times \%\ evaporation\ \ from\ surface \end{cases}$$

Figure 4. Flow diagram of water accounting



ii. TRWR – Total Renewable Water Resources

iii. PUWR – Potentially Utilizable Water Resources

iv. Parts of the environment and navigation flows are met from unutilizable TRWR and the other parts are met by PUWR

v. Domestic sector includes livestock sector water needs.

Non crop ET is the evaporation and transpiration from the swamps, bare fields, and tress and other crops which the water withdrawals are not intended for.

The un-utilizable flows to sea or sink is estimated as

$$Un\ utilizable\ \ flows\ to\ sea = \begin{cases} Balance\ \ flow^{irri} \times \%\ unutilizable\ of\ \ balance\ \ flow^{irri} \\ Balance\ \ flow^{Dom} \times \%\ unutilizable\ of\ \ balance\ \ flow^{Dom} \\ Balance\ \ flow^{Ind} \times \%\ unutilizable\ of\ \ balance\ \ flow^{Ind} \end{cases}$$

The utilizable flows to sea from the surface return flows and groundwater recharge are estimated as

$$Utilizable\ return\ \ flows\ to\ sea = \begin{cases} \mathrm{Re}\, turn\ \ flows\ to\ surface \times \% return\ \ flows\ to\ sea + \\ Ground\ \ water\ rech\arg e \times \% ground\ \ water\ rech\arg e\ to\ sea \end{cases}$$

The primary water supply is defined as

$$\begin{aligned} \Pr imary\ water \sup ply &= \Pr ocess\ evaporation + Non\ \ process\ evaporation + \\ &\quad un\ utilizable\ \ flows\ to\ sea + utilizable\ returnflows\ to\ sea \end{aligned}$$

The total depletion of the primary water supply is

$$Total\ \ depletion = \Pr ocess\ evaporation + Non\ \ process\ evaporation + un\ utilizable\ \ flows\ to\ sea$$

Three indicators of the extent of water development and use in the basin is given by

$$Degree\ of\ \ development = \frac{\Pr imary\ water \sup ply}{PUWR - environmental\ \ flows\ \ from\ PUWR}$$

$$Depletion\ \ fraction = \frac{Total\ \ depletion}{\Pr imary\ water \sup pply}$$ and

$$Grounf\ \ water\ abstraction\ ratio = \frac{Total\ \ ground\ \ water\ \ withdrawals}{Total\ available\ groundwater \sup ply}$$

2.9 PODIUMSIM Model applications and publications

The upgraded model, PODIUMSIM, is adapted to India and China at river basin level. The model considers 19 river basins for India and 9 river basins for China. The adapted versions for the two countries PODIUMSIM India and PODIUMSIM China, the data and the model brochure are available in the ICID and IWMI web sites (www.icid.org and www.iwmi.cgiar.org/tools/podiumsim.html).

Two papers were written on the river basin water supply and demand variations in India and China. The initial draft, “Water Supply and Demand Variation across river basin India”, that is available in the ICID website, is revised and published as a IWMI Research Report (Amarasinghe et al, 2005). Another draft report highlighting the water supply and demand of Chinese river basins was preferred and circulated separately.

Capacity Building

The IWMI/IFPRI component of CPSP has contributed various capacity building activities including support for PhD Studies, PODIUMSIM training programs etc. The project supported two PhD studies:

1. Dr. Liao Yongsong of Chinese Center for Agricultural Policy has completed his PhD studies under the PODIUMSIM model development component.
2. Dr. Charlotte De Fraiture of IWMI has completed her PhD studies under the WATERSIM model development component.

In addition to supporting PhD studies, IWMI has also conducted several model development or orientation workshops and supported attendance of several conferences during the project period. This list is given below.

Workshop Name	Venue and Date	Number of Participants
Training workshop for PODIUMSIM for participants of India, China and Pakistan	Colombo, Sri Lanka November 2001	5 (2 India, 1 China, 1 Pakistan)
PODIUMSIM India model revision	Colombo, Sri Lanka May 2002	2 (2 from India)
Presentations at 52nd ICID Congress in Canada by Mr. A.K. Shukla of Central Water Commission	Montreal, Canada, August 2002	3 (1 from India, 2 from Sri Lanka)
PODIUMSIM China- Orientation workshop	Beijing, China January 2003	6 (all Chinese participants)
PODIUMSIM China model revision	Colombo, Sri Lanka March 2003	1 Chinese participant
PODIUMSIM India and China - Orientation workshop	Delhi, India November 2003	10 (2 from IWMI, 4 each from India and China)
India National Consultation	Delhi, India November 2003	2 (From IWMI)
IWMI / ICID Scenario Development Orientation Workshop for India & China	Moscow, Russia September 2004	22 (11 from India, 6 from China, 1 from Malaysia and 4 from IWMI)
Watersim for CPSP	ICID Congress, Beijing China, September 2005	

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