A S.D. Model for Rational Exploitation and Utilization of Water Resources in Arid and Semi-arid Areas

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Abstract

This model, composed of 12 subsystems and more than 220 equations, disccusses various factors concerning water resource and the feedback relations of these factors. Through emulations of the different decision plans, it puts foreward the most favorable plans for rational and economical exploitation of water resources, the improvement of water utilization ratio and the best use of water under the conditions of a sound ecological balance.

1 Purpose of the Model

Xinjiang,short for Xinjiang Uygyr Autonomous Region,with an area of more than 1.66 million square kilomters,occupying one-sixth of the ccountry's total area is a typical arid and semi-arid area with a continental climate in the temperate zone since it is situated in the deep hinterlamd of Eurasia and far from seas and oceans. Its annaul precipitation everages 150 mm while its evapotranspiration runs as high as 1000-1500. More than 93% cultivated areas depend on irrigation, the same is true of artificial grassland and artificial forests. Therefore water means a great deal in Xinjiang. Wherever there is water, an oasis is created along with what is known as the oasis economy. Water is not only the lifeline of agriculture but in the long run, the factor of restriction in the progress of economic development in Xinjinag. The contradiction between supply and demand of fresh water will become sharper and sharper as the population grows and economy develops. The decition-makers at all levels have been showing great concern for such problems as how to tap and use rationally and economically the limited water resources to meet the ever increasing demand for water from people, animals and economic activities, and how to get the best ecological, economic and social results out of the limited water resources under the condition of maintaining ecological balance. And the main purposes of building the model are to explore possible paths and methods for solving the problems and through quantitative analyses to make a fair assessment of how much the water resources can guarantee the economic development and how much the investment should be made in tapping and making good use of water resources.

2 System Interface and Model Structure

2.1 System interface

Since what we are discussing are systems of exploitation and utilization of water resources in Xinjiang from a macro strategic point of view, we here only focus our attention on the equilibrium of supply and demand of water resources. Considering the limits of a computer capacity and the run-time, we have to set a limit to the scale of the model but all those quantitative factors concerning water supply and demand are included in the systems.

2.2 Main Structure of the Model

The model covering water supply, economized water consumption, water utilization, funds and some other aspects, is composed of twelve subsystems which are as follows: artesian water diversion, water impounding, groundwater supply, antiseeping, spray-drip irrigation, industrial water, water for daily living of urban and rural people and for common facilities, water for livestock, irrigation of cultivated land, forest irrigation, grassland irrigation as well as scientific and technological development.The main feedback relations of the model see figure 1.

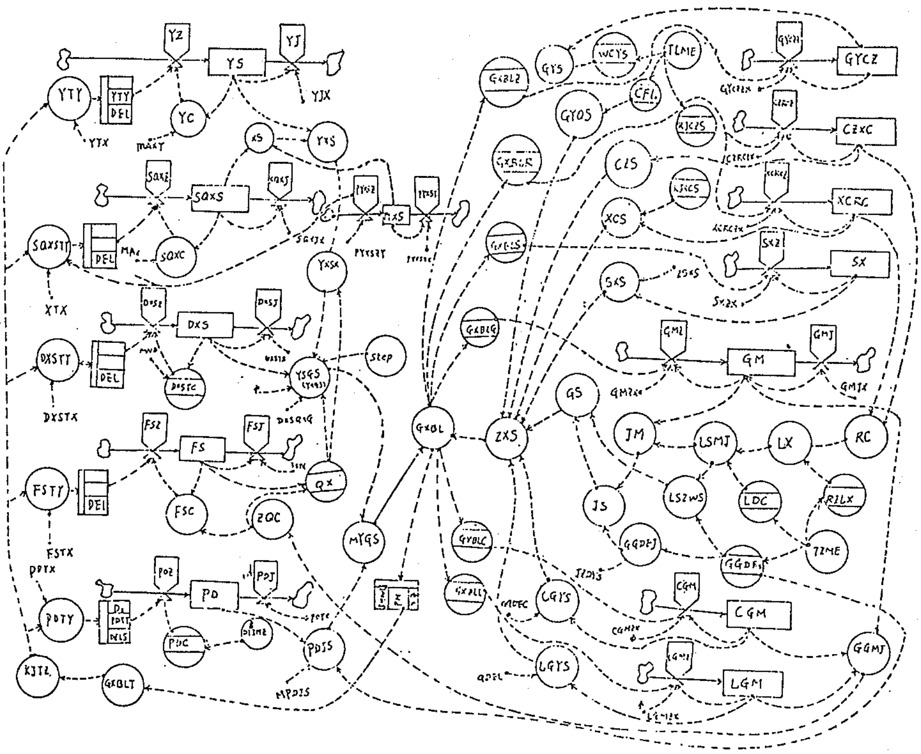

Figure 1. S.D. flow diagram of exploitation and utilization of water resources

YS	amount of water diverted
YZ	increased amount of water diverted
YT	decreased amount of water diverted
YTX	coefficient of the decreased amount of water diverted
YTY	investment in water diversion
YC	cost per unit of water diverted
YTX	coefficient of the investment in water diversion
KJTZ	investment in exploiting water resources and economizing water consumption
XS	water impounded in reservoirs
SQXS	water impounded in reservoirs in mountain areas
PYXS	water impounded in reservoirs in plain areas
SQXZ	increased water reservoir-impounded in mountain areas
SQXJ	decreased water reservoir-impounded in mountain areas
SQXJX	coefficient of the decreased water reservoir-impounded in mountain areas
SQXSTY	investment in water impounding in mountain areas
SQXC	cost per unit of water impounded in mountain areas
PYXC	cost per unit of water impounded in plain areas
XTX	coefficient of the investment in water impounding
PYXSJX	coefficient of decreased water impounded in plain areas
PYXZ	increased water impounded in plain areas
PYXJ	decreased water impounded in plain areas
DXS	groundwater
DXSZ	increased amount of groundwater
DXSJ	decreased amount of groundwater
DXSJX	coefficient of the decreased groundwater
DXSTY	investment in tapping groundwater
DXSTC	cost per unit of groundwater exploited
DXSTX	coefficient of investment in tapping groundwater
PD	areas under spray and drip irrigation
PDZ	increased areas under spray and drip irrigation
PDJ	decreased areas under spray and drip irrigation
PDJX	coefficient of the decreased areas under spray and drip irrigation
PDTY	investment in spray and drip irrigation
PDC	cost of spray and drip irrigation
PDTX	coefficient of investment in spray and drip irrigation
FS	antiseeping degree of irrigation canal
FSZ	increased length of antiseep canal
FSJ	decreased length of antiseep canal
FSJX	coefficient of the decreased degree of seeping
FSTY	investment in antiseeping projests
FSTX	coefficient of the investment in antiseeping
YXS	water diverted and impounded
YXSX	effective water diverted and impounded
QX	rate of use of irrigation system
GYCZ	industrial output value
GYCZZ	increased industrial output value
GYCZZX	growth rate of industrial output value
GXBLZ	ratio between supply and demand
GYS	industrial water demand
WCYS	water needed for producing 10,000 yuan output value
CZRC	urban population
CZRCZ	increased urban population
XCRC	rural population
XCRCZ	increased rural population
SX	total head of livestock
SXZ	increased head of livestock
FSC	cost of antiseeping projects
SXZX	growth rate of livestock
SXS	water for livestock
ZSXS	water for per head of livestock
XCRC	rural population

XCRCZ	increased rural population
SX	total head of livestock
SXZ	increased head of livestock
FSC	cost of antiseeping projects
SXZX	growth rate of livestock
SXS	water for livestock
ZSXS	water for per head of livestock
GCXS	industrial water and livestock water
GYQS	industrial water
CFL	rate of water circulated
CZS	water for towns and cities
XCS	water for daily living of rural people
RC	total population
GM	cultivated areas
GMZ	increased cultivated areas
GMJ	decreased cultivated areasa
GMJX	rate of the decreased cultivated areas
LX	demand for grain
RJLX	per capita demand for grain
JM	areas devoted to cash crops
LSMJ	areas devoted to grain crops
LSZWS	water needed by grain crops
GGDES	irrigation norm for grain crops
JS	water needed by cash crops
GGDEJ	irrigation norm for cash crops
GS	water for cultivated land
LGM	irrigated forest areas
LGMZ	increased irrigated forest areas
LGMZX	growth rate of irrigated forest areas
GXBLA	multiplier of the rate between supply and demand
CGM	area of irrigated graasland
CGMZ	increased area of irrigated grassland
CGMZX	growth rate of irrigated grassland area
ZGGMJ	total irrigated area
ZXS	total demand for water
LGYS	water for forest irrigation
CGYS	water for grassland irrigation

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L  YS.K=YS.J+DT*(YZ.JK-YJ.JK)
R  YJ.KL=YS.K/YJX
R  YZ.KL=YTY.KL/YC.K
R  YT.KL=YTX.K*KJTZ.K
A  XS.K=SQXS.K+PYXS.K
L  SQXS.K=SQXS.J+DT*(SQXZ.JK-SQXJ.JK)
R  SQXJ.KL=SQXS.K/SQXJX
R  SQXZ.KL=SQXSTY.KL/SQXC.K
R  XST.KL=XTX.K*KJTZ.K
L  PYXS.K=PYXS.J+DT*(PYXZ.JK-PYXJ.JK)
L  DXS.K=DXS.J+DT*(DXSZ.JK-DXSJ.JK)
R  DXSJ.KL=DXS.K/DXSJX
R  DXSZ.KL=DXSTY.KL/DXSTC.K
R  DXST.KL=KJTZ.K*DXSTX.K
L  PD.K=PD.J+DT*(PDZ.JK-PDJ.JK)
R  PDZ.KL=PDTY.KL/PDC.K
R  PDJ.KL=PD.K/PDJX
L  GYCZ.K=GYCZ.J+DT*GYCZZ.JK
R  GYCZZ.KL=GYCZ.K*GYCZZX*GXBLZ.K
A  GYS.K=GYCZ.K*WCYS.K
L  CZRC.K=CZRC.J+DT*CZRCZ.JK
L  XCRC.K=XCRC.J+DT*XCRCZ.JK
L  SX.K=SX.J+DT*SXZ.JK
R  SXZ.KL=SX.K*SXZX
A  SXS.K=SX.K*ZSXS
A  GCXS.K=GYQS.K+CZS.K+XCS.K+SXS.K
A  GYQS.K=GYS.K-GYS.K*CFL.K
A  RC.K=CZRC.K+XCRC.K
L  GM.K=GM.J+DT*(GMZ.JK-GMJ.JK)
R  GMJ.KL=GM.K*GMJX
A  LX.K=RJLX.K*RC.K
A  JM.K=GM.K-LSMJ.K
A  LSZWS.K=GGDES.K*LSMJ.K
A  JS.K=GGDEJ.K*JM.K
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3 Potency of the Model and Policy Analyses

When the above-mentioned preparation and examination work has been well done, we take pains in making alterations and test runs so as to perfect the S.D. model on a computer and to build a sound interactive system by selecting different parameters and entering various table functions. All these stand as a guarantee to enable us to trace and simulate indoors such a complicated system as exploitation and utilization of Xinjiang water resources, to carry out simulation experiments with every possible variable, and to investigate the while process of exploitation and utilization of water resources from a dynamic point of view. Through the repeated simulation experiments the model shows us the dynamic states in different sections and illustrates the prospects of exploitation and utilization of water resources in Xinjiang (see figure 2). From the results of emulations of many plans, a conclusion is drawn as below.

3.1 If a comprehensive scientific method is adopted in the management of water resources, it will never happen that the speed of economic development in Xinjiang is slowed down just because of lack of water. The general trend of exploitation and utilization of water resources in Xinjiang,came out as the result of emulations of different decision plans, is illustrated as follows.

By the year of 2000, the population in Xinjiang will be as many as 17.7 x 10^6; grain yield 75 x 10^8 kg; the value of industrial output 30 x 10^9 RMB yuan; livestock 4 x 10^7 head; meanwhile the demand for water will increase by 23% comparing with what in 1986, that is more than 51 x 10^9 cubic meters; groundwater exploited 4.4 x 10^9 cubic meters; groundwater impounded in reserviors 8.4 x 10^9 cubic meters; artesian water diverted 38.3 x 10^9 cubic meters; the sum of total investments needed in projects of exploitation and utilization of water resources 5 x 10^9 RMB yuan.

By the year of 2020, water exploited will be more than 58 x 10^9 cubic meters and by the middle of the next century, it will be upped to 60 x 10^9 cubic meters. In Xinjiang,water that can be exploited and used is expected to be 91.6 x 10^9 cubic meters (of which surface water is about 66.4 x 10^9 cubic meters and ground water about 25.2 x 10^9 cubic meters), of which 24 x 10^9 cubic meters are used to maintain a favorable ecological environment, therefore there are still 67.6 x 10^9 cubic meters of water that can meet the demand of people's daily lives and economic development. It is obvious that so long as a comprehensive scientific management is practised in water exploitation and utilization while special efforts are devoted to the development of water-saving techniques, it can be taken as granted that in Xinjiang, water resources will never become a drag on the progress of economic development.

3.2 Since Xinjiang is located in an arid and semi-arid area,special attention should be paid to rational and economical use of water. It comes out clearly, as the results of emulations of the model, that the large-scaled water diversion compaigns characterized by the principle of tapping water resources is now a closed chapter, and during the eighties of the century a new trend has come into existence which is characterized by the principle of tapping water resources while economizing on water.Recently, there is still a potential in tapping water resources (mainly the ground water) but as time goes onto the twenties of the next century, the exploitation of water resources will reach its rational and economical superior limit, then follows another new trend giving the first place to economizingwater. It is true to any area that the amount of water resources is a limited number evenif the area is endowed with rich water resources. As time goes on, population will grow and economy will develop, the amount of water demanded will simultaneously rise up. If rational and economical use of water is neglected, sooner or later, it will bring about water crisis. Therefore, it is becoming urgent to take notice of the rational and economical use water, and to create a water-saving agriculture, awater-saving industry as well as a water-saving society.

3.3 Attention should be paid to leave enough water for a sound ecological environment and to prevent water from being polluted Water is one of the primary demands for the existence of living beings. In arid and semi-arid areas, the ecological environment is adverse, water becomes the very determining material prerequisite for maintaining the ecological environment and to prevent water from being polluted Water is one of the primary demands for the existence of living beings. In arid and semi-arid areas, the ecological environment is adverse, water becomes the very determining material prerequisite for maintaining the modest ecological environment. Once water is over-diverted, rivers will become dry, the natural vegetation along the revers will wither up and finally die, the lakes depending water supply from the rivers will be dried up, these in turn will cause sand crossion accelerated and the climate deteriorated, and moreover these will threaten the productive activities and the existence of human beings. Therefore, considerable becomes the very determining material prerequisite for maintaining the modest ecological environment. Once water is over-diverted, rivers will become dry, the natural vegetation along the revers will wither up and finally die, the lakes depending water supply from the rivers will be dried up, these in turn will cause sand crossion accelerated and the climate deteriorated, and moreover these will threaten the productive activities and the existence of human beings. Therefore, considerable attention should always be paid to leave enough water for a sound ecological environment and to prevent water from being polluted when plans for exploitation and utilization of water resources are to be taken into consideration.

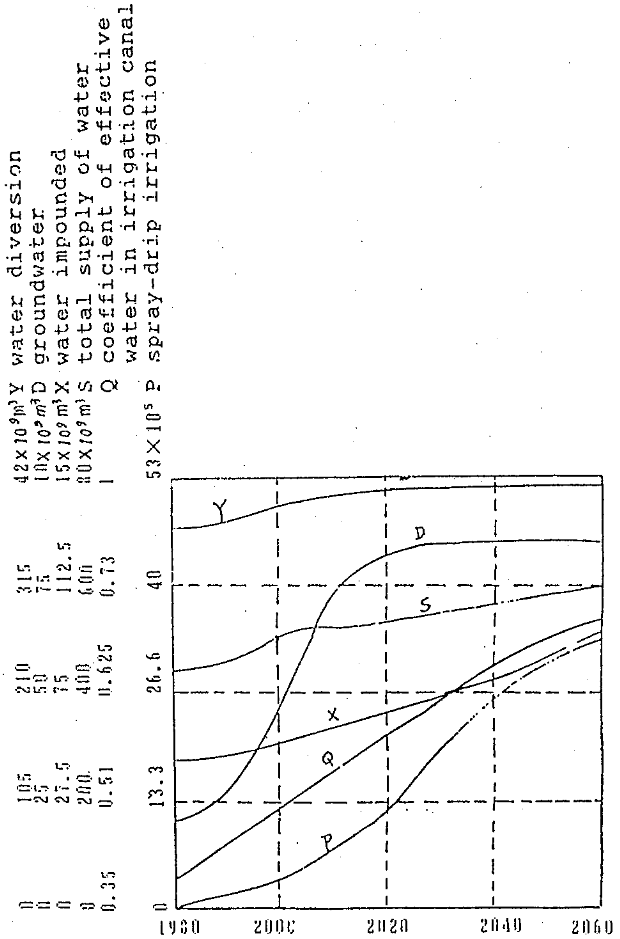

Figure 2. result of performance

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