THE JAVA SPATIAL MODEL AND ITS USE FOR POLICY MAKING IN WATER RESOURCE MANAGEMENT

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ABSTRACT
Strong demographic changes and increasing economic activities over the next 25 years will stretch available resources of land, water and environment on the island of Java to the limit. A doubling of urbanized area has been projected by 2030. Uncontrolled settlement and non-adapted land-use practices up to now have had a strong adverse impact on runoff: higher peak flows and lower low flows are being experienced, resulting in increased flooding and shortages in water supply. Climate change is expected to further re-enforce extremes by causing more high intensity storms as well as drought situations.
In these circumstances an effective protection through zoning and regulation will be necessary to prevent further degradation of water resources and upgrade as much as possible existing adverse conditions.

The new spatial law Nr 26 (2007), with its orientation to sustainable resource management and protection provides a framework to address the conservation requirements to protect water resources interests. There remains however a major challenge to translate the water resources interests into appropriate zoning and regulation.

A prototype spatial model for Java is being developed. This model will facilitate dynamic projections of settlement and allow to prepare consistent settlement projection as input to infrastructure planning, and to support policy analysis.
The paper presents the set-up and use of the Java Spatial Model, discussing key drivers for urban land-use change, - the structure of the model, - its use in policy making (e.g. conflict resolution on the use of the space for different purposes, for different scenarios), and presentation of initial results. The paper further discusses the interactions between space and water; using results for the Jratunseluna river basin an approach is explored for an efficient regulation of land-use (zoning) to serve water interests

Key words: spatial planning, modeling, conservation, water resources,

1. INTRODUCTION

Strong demographic changes and increasing economic activities over the next 25 years will stretch available resources of land, water and environment on the island of Java to the limit. A doubling of urbanized area has been projected by 2030. Uncontrolled settlement and non-adapted land-use practices up to now have had a strong adverse impact on runoff: higher peak flows and lower low flows are being experienced, resulting in increased flooding and shortages in water supply. Climate change is expected to further re-enforce extremes by causing more high intensity storms as well as drought situations.
The situation is especially serious because the strong changes increase on the one hand the demand for water and flood control and at the same time threaten to affect the supply in an adverse way, further emphasized by climate change.
In these circumstances an effective protection through zoning and regulation will be necessary to prevent further degradation of water resources and upgrade as much as possible existing adverse conditions.

The interactions between Water and land-use are presently high on the political agenda. Both the new Water Law (2004) and new Spatial law (2007) call for an integration; it is considered the next step in advanced water management. This interest is not unique for Indonesia; in the Netherlands for example this issue has also gathered increasing attention; recently the "National policy note for spatial planning", the 4th "National note on water management", and the special report of the "Commission on water management for the 21st century", concluded that a much stronger integration of both policy disciplines is required.
The main themes for water as elaborated in the 4th "National policy note on water management" are security, drought alleviation, emission control, sanitation of polluted water bottoms, and water excess. The total claim on space associated with those themes is about 500,000 ha. This constitutes a strong increase over the present 765,000 ha of (allocated) space claims by the water sector in the Netherlands.

The New Spatial law specifically addresses conservation with strong linkage to water; the spatial law specifies a minimum target of maintaining 30% of forest in each water catchment area (DAS). Besides this general requirement a catchment specific analysis should indicate if additional conservation zoning is required addressing issues such as conservation of flow pattern (favorable peak/low flow ratio) and erosion. It is anticipated that a more diversified zoning is needed to represent conservation interests related to water; such zoning can range from limiting specific land functions or setting specific requirements (e.g. for infiltration) towards a complete ban on new urban developments. It should be noted that such zoning policies are not developed in isolation and especially in regions with a high pressure on land this is a complicated task.

Java island is a region that suffers from scarce land resources. If large land claims are developed for the water sector of Java then this will have strong impact on other land consuming sectors. Therefore a rational basis, using quantified information from different sectors, will be required to prepare for decision making; this means a quantification of interests and impacts. An essential role in this quantification will be played by a spatial modeling by which trends and substitutions in the use of space triggered by socio-economic developments can be traced associated with alternatives in water- and spatial plans.

The present paper discusses the set-up of a prototype Java Spatial Model[1] (JSM) and its application. Section 2 defines space-water interactions and the role of projection of spatial development. Section 3 discusses the set-up of the prototype JSM. Section 4 illustrates space-water interactions for the Jratunseluna basin. Key observations and findings are summarized in section 5.

2. SPACE-WATER INTERACTIONS

The two-way interactions between space- and water resources development are sketched in Figure 1, they can be briefly described as follows

1) Spatial settlement influences demands for water, puts stress on the environment, and influences run-off - and morphological processes in the catchment.
2) Water demands, water availability, high (flood) flows, pollutant loads, adverse catchment conditions, form input to water resources planning, which aims at optimizing the performance of water systems in the river basin. A wide range of measures are available to adjust performance at a certain cost.
3) Zoning and associated regulation is necessary to implement particular water resources measures (e.g. catchment protection). Water resources related impacts form input to an overall assessment of different usage of space.
4) Spatial planning results in a zoning of available land indicating allowed functions for parcels of land. This is based on a balancing of impacts from the different sectors.
5) Settlement over a planning time horizon will result from socio-economic development involving different markets such as labor, housing etc., as well as zoning directives. Projection of settlement allows to trace potential conflicts in the use of pace and is therefore a man tool for policy making

Spatial development and sectoral (water) analysis have a different spatial scale (Figure 2): to represent the relative attractivity of regions for settlement and potential migrations a Java wide scale will be necessary for projection of settlement; water resources systems inter-relationships are bounded within river basins.

[1] model prepared in the project “Integrated planning of space and water”; project commissioned by the Netherlands Partners for Water and carried out for the Ministry of Public Works, Direktorat Jenderal Penataan Ruang; executed by a consortium of Delft University of Technology, Demis BV, Delft Hydraulics and MLD.

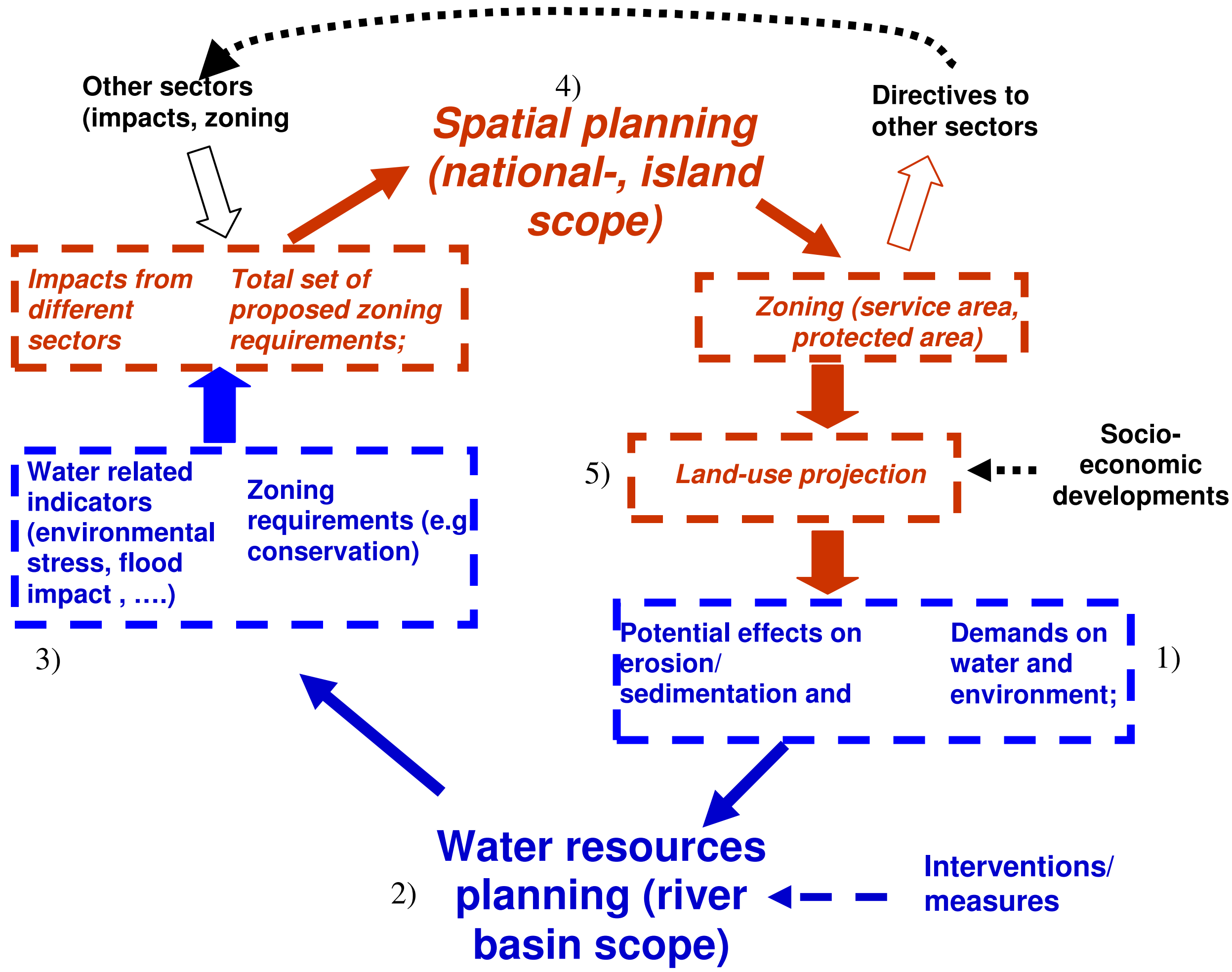

Figure 1: Overview space-water interactions

3. JAVA SPATIAL MODEL

3.1 Introduction

A prototype spatial model is being prepared for the whole of Java. Starting points for the development of the Java Spatial Model is the pilot spatial model as developed in the BWRP project (BWRP, 2003) and experiences with the development and application of a land-use and transport interaction model for the Netherlands (Zondag, 2007; Zondag and de Jong, 2005). This section describes the drivers of urban land-use change on Java (identifying what needs to be modelled), the structure of the Java Spatial Model and the use of the modelling in policy making.

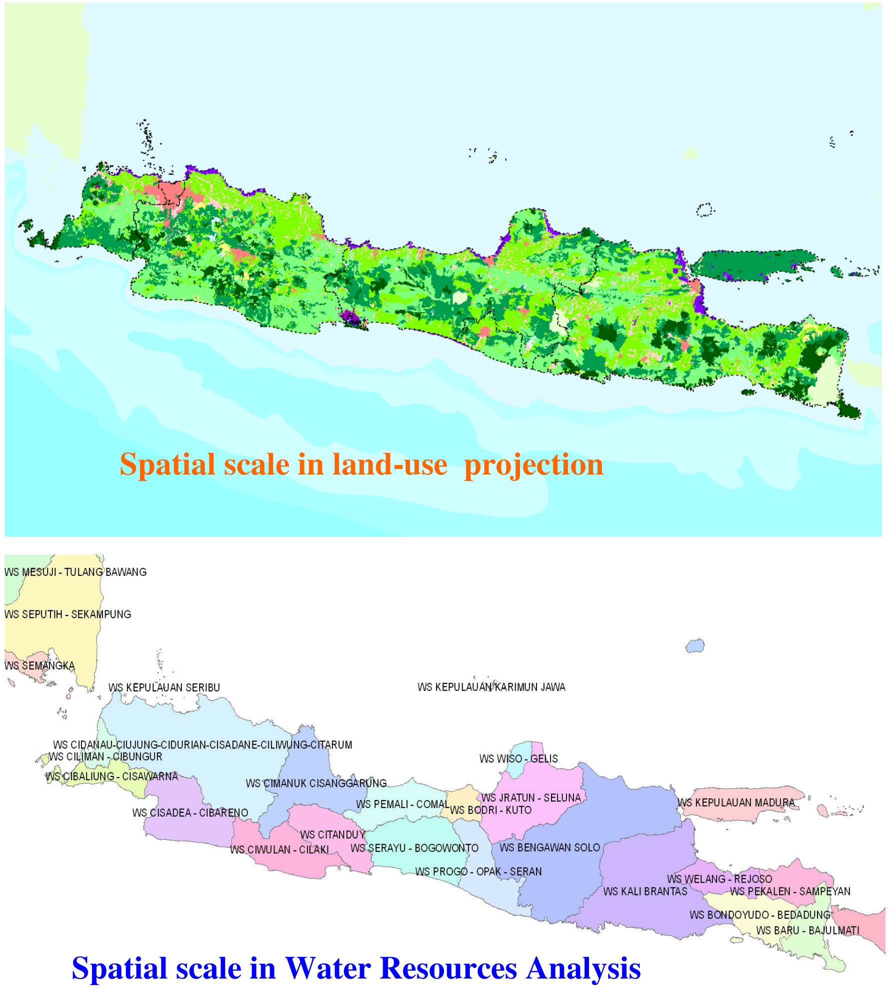

Figure 2: Scales in spatial projection and water resources analysis

3.1 Drivers of land-use change

The ongoing transformation of non-urban area into urbanized land is the result of developments in spatial markets like the housing market, labor market or transport market. These markets change under influence of several interacting driving forces; important drivers are demographic and socio-economic drivers. A good understanding of these drivers, how they are going to develop and differ among regions, is important for modeling future urban land-use.

Demographic drivers are especially important to project future residential land demand. Key drivers for additional residential land-use are:

- Population growth;
- Household size reduction;
- Increasing use of land resources per household as wealth grows.

Table 1 shows the average annual growth in the period 1990-2000 for the first two factors by province on Java; the data show that the population growth was rather unevenly distributed over Java with a high growth in the West Java province; it also indicates the decline in average household size was in the period 1990 - 2000 a more dominant factor explaining the growth in urban land-use than the population growth; increasing use of land due to growth in wealth is more difficult to estimate as detailed data on land-use is missing; however international research shows that this is a substantial factor.

	Population	Average Household size
DKI Jakarta	0.16%	-2.4%
Jawa Barat (incl. Banten)	2.17%	-1.3%
Jawa Tengah	0.82%	-1.2%
DI Yogyakarta	0.68%	-1.7%
Jawa Timur	0.63%	-1.3%

Table 1: Demographic indicators (1990-2000) for Java

Establishing the total need for additional residential land requires multiplication of these three factors. If each factor will grow with 20% in the next 20 years (less than 1% population growth a year, 1% reduction in household size a year and 1% increase in land use by household a year) then the total additional need for residential land is above 70%. An important observation is that the increase in residential land-use is much higher than the population growth; for Java this growth can easily be 70% or more depending on scenario settings. Another observation is that this growth will be very unevenly divided over Java. Simply applying a standard factor is therefore no option and a spatial model is needed to capture the regional differences

Key *Economic drivers* of land-use change are:

- Economic growth and associated employment growth;
- Land-use by employee;
- Changes in economic structure

The demand for industrial and commercial land is driven by changes in employment for these sectors. Key measure for economic growth is the growth of GDP; the economic growth consists of a productivity component and an employment component. The GDP growth over the last 15 years on Java is more than a factor 3 higher than the growth in employment showing that the productivity component is larger than the employment component. It should be noted that substantial differences exist in employment growth between the various regions on Java. For example, the average annual growth rate of employment in Jakarta has been a factor three higher than for the provinces of East or Central Java.

The economic structure of Java has changed significantly over the last 15 years; the employment share of agriculture has declined from 49% in 1990 towards 36% in 2005 (BPS data). The employment share of the industrial sector has increased form 11 to 22% in the same period (service sector from 40% to 42%). It is obvious that these changes in economic structure were an important driver of the growth of industrial and urban land-use. It is likely that in the future an additional shift from employment in the agricultural sector towards the industrial and service sectors will take place.

The *trends in spatial developments* depend on the spatial scale level: at the inter-regional level a centralization trend can be observed driven by agglomeration forces (e.g. Greater Jakarta region); however at a regional level suburbanization (or decentralization) is the dominant trend; on Java this can be observed in the regencies neighboring Jakarta in the provinces of West-Java and Banten. Key drivers of suburbanization are housing preferences and improved transport conditions (higher car ownership rates, improved road conditions) facilitating longer commuting distances.

3.3 Structure of the prototype Java Spatial Model

Key principles in the design of the Java Spatial model are the following:

- Layered structure to capture the different spatial trends of centralization at an interregional level and suburbanization (or decentralization) within a region;
- The modeling is dynamic and uses time steps of one year; this reflects the incremental nature of spatial changes and enables to model the time path dependency of developments;
- Key feature of the model is its spatial detail, the model is capable of calculating the impacts on the spatial distribution of residents/employment and associated land-use changes of different socio-economic (or demographic) scenarios and/or policies at the level of desa units;
- Flexible structure based on the use of separate interacting modules.

Figure 3 presents the structure of the model comprising a socio-economic module, addressing differences in development at a regional level, and a spatial allocation module addressing the changes in number of residents and employment and associated land-use changes at a local desa level (27000 desa's on Java). Further a post processing module is being developed to generate (at present a limited number of) indicators for land-use, agriculture and water.

3.4 Data and calibration

The methodologies applied in the socio-economic module and spatial allocation module are tailored to available data conditions; this means in particular that advanced regional economic modeling methods, using disaggregated discrete choice approaches, to model residential and firm choices, are currently not feasible. Key data bases that are collected and used in the modeling are;

- The PODES 2005 database (at desa level): the basic data base for the spatial allocation model as it includes data on all desa units in Java;
- Landsat 2004 land-use data for Java is used to check on the land-use data in the PODES 2005 database; the quality of the PODES data is questionable;

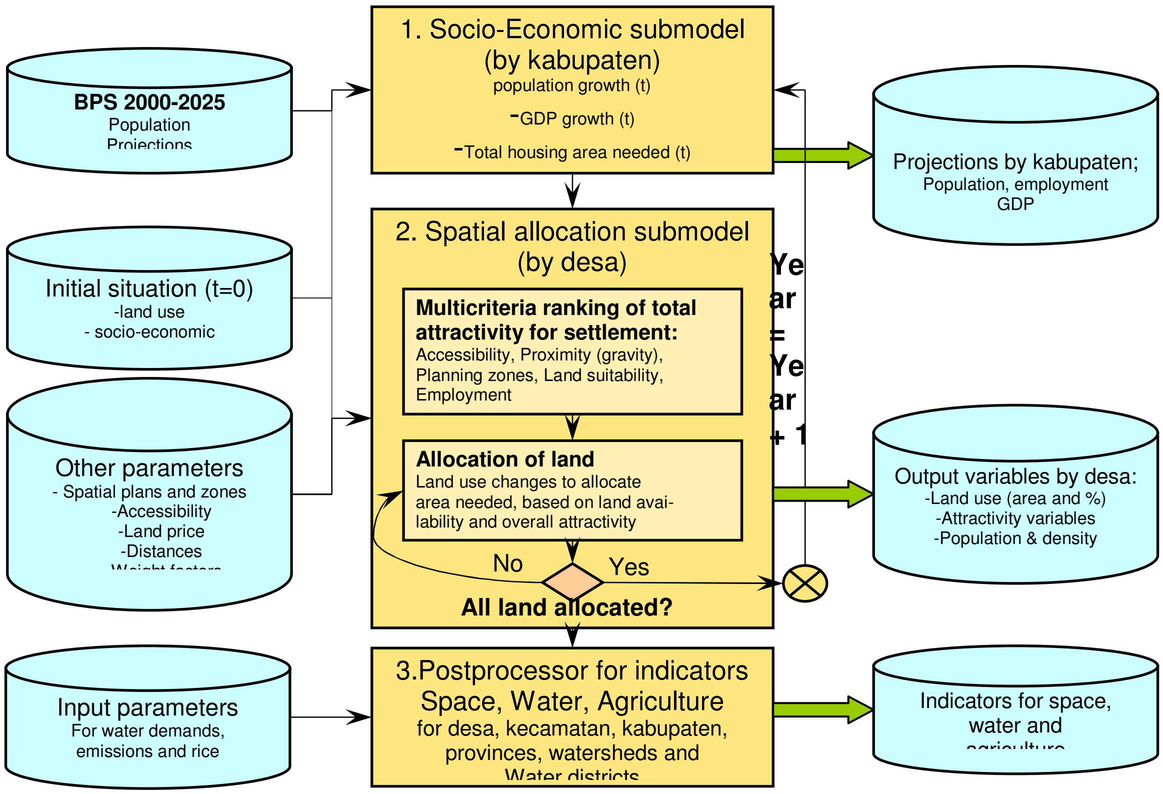

Figure 3: Functional flow diagram of the Java Spatial Model

- At Kabupaten level time series data are collected from BPS for the period 1990-2005 for all Kabupaten on Java (Dalam Angka data). This data and Sensus 1990 and 2000 data will be used to calibrate the socio-economic module;
- Remote sensing data is processed to gather information on land-use for the Jratunseluna region for 2000 and 2006; this time interval will be used to calibrate the Spatial allocation module.
- To apply the model, exogenous scenario's on population and economic development for the whole of Java are needed; BPS data on long term population projections 2000-2025 is used.

3.5 Use of modeling in policy making

Two key functions of the Java Spatial Model are:

- Forecasting instrument; exogenous long term socio-economic and demographic scenarios for Java are translated into detailed spatial projections for population/employment and associated changes in land-use;
- Policy making instrument for the use of space: the model calculates the impacts of alternative land-use policies on the spatial distribution of residents/employment and associated land-use.

The contribution of the first function is rather straightforward as different sectors (e.g transport, energy, water, etc.) need this type of detailed spatial information as input for their planning. It is clear that an improved quality and consistency of this critical input data will improve policy making in these sectors. In Section 4 this functionality of the JSM will be further elaborated for the water sector.

The second function of the JSM, its contribution to policy making, is more complex as spatial policy making is in nature a multi-sector activity. Many different sectors (e.g. housing, forestry, agriculture, water, etc.) put claims on land and it is a key function of spatial planning to develop an integrated multi-sector spatial plan. The spatial planning agency has to perform a multi-sector analysis, including the land claims from the different sectors, to develop such integrated spatial plan.

Such a multi-sector analysis will require to resolve conflicting claims and to make trade-offs. For example, conservation in upstream regions might result in a shift of residents and firms to downstream regions. Such additional need for urban land in downstream regions might conflict with the preservation of sawah areas. Only a multi-sector analysis, using a quantitative instrument (like the JSM), is capable of identifying the kind and size of chooses which need to be made. Such information is critical to inform policy makers and develop a spatial plan which contributes as good as possible to overall societal welfare.

By providing transparency, application of such quantitative approach can strongly facilitate the process of negotiations with different sectors and tiers of government which is necessary to establish an overall agreed spatial plan necessary for implementation.

The political process of negotiations with different sectors and tiers of government is illustrated in Figure 4. As shown a land-use model can help a Spatial Planning Agency in this process by improving the collection and processing of spatial data, communication via presentation of alternative land-use forecasts in thematic maps and identification of areas of conflict and trade offs. The process of interaction with the sectors is dynamic in nature but needs clear procedures for interactions to clarify discussion points and deliver well defined “Spatial plans” at regular intervals in time.

Zoning and associated regulation forms the main instrument for policy making. This covers two main purposes: protection of interests in the different sectors (e.g. erosion) and harmonization of the use of space by the different sectors.

There exist many different types of zoning, for example for water

- Flood zoning
- zoning for emission control
- Watershed conservation (e.g. to prevent erosion)
- Groundwater protection, etc

The definition of the optimal zone and methodology for its derivation will be different for each of those aspects. In the case of Flood zoning the optimum can be defined as the zone that provides the best reduction of flood damages in comparison to the costs of implementing the zoning and flood damage control measures. In the case of emission management the optimum zoning will usually also be based on non-monetary values, for example the minimization of the impacts on the ecological state of the water-system. In the case of watershed protection a mixture of monetary and ecological indicators may be needed.

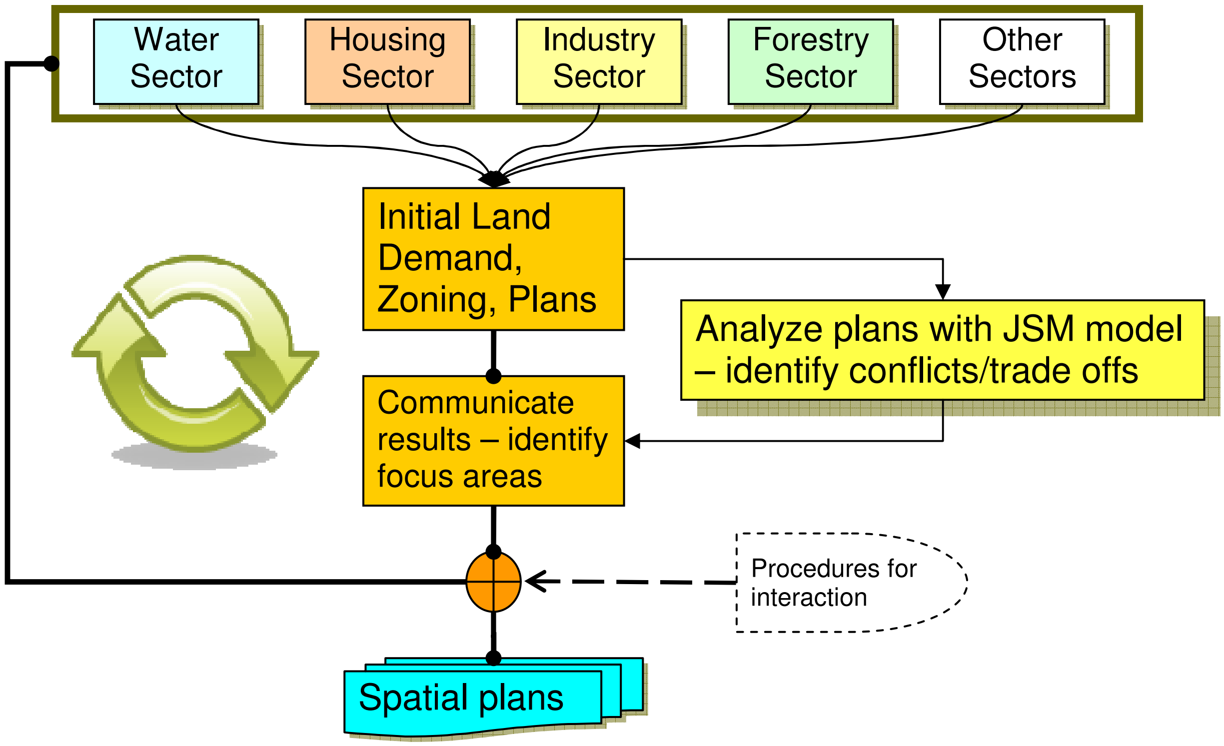

Figure 4: Role of the spatial projection model in the negotiation process to implement spatial plans

Different spatial levels need to be differentiated. For example for zoning for the water sector usually river basin wide interests and interactions will need to be considered; this may be complemented at the local level with more detailed/additional zoning

4. JRATUNSELUNA CASE

4.1 General

Main water resources themes in the basin comprise water shortage (irrigation, DMI water supply), flooding, and deterioration of watersheds. The emphasis on one or the other differs strongly for the different localities in the basin: flooding and drainage problems are situated on the low laying and flat coastal plains while problems with watershed deterioration are localized in the sloped upstream catchment areas.
Spatial development plays an imported role in addressing those themes.

Below two distinctive space-water interactions, demand projection and zoning (indicated in Figure 1), are explored for the Jratunseluna river basin. The influence of spatial development on water resources planning are indicated.

4.2 Spatial projection and water balance analysis

Water demands for irrigation and urban water supply form input to the water balance of the basin. The water balance needs to be analyzed to determine how well the different demands can be satisfied from the available water and to evaluate measures to make maximum use of available water. Figure 5 presents a schematization for the water balance for the Jratunseluna basin: the branches, representing conveyance of water, and a set of different kinds of nodes, representing activities with water (irrigation, storage, diversion, low flow, ….), represent the features of the basin with relevance to the water balance. This network can be adjusted to provide any required level of detail.

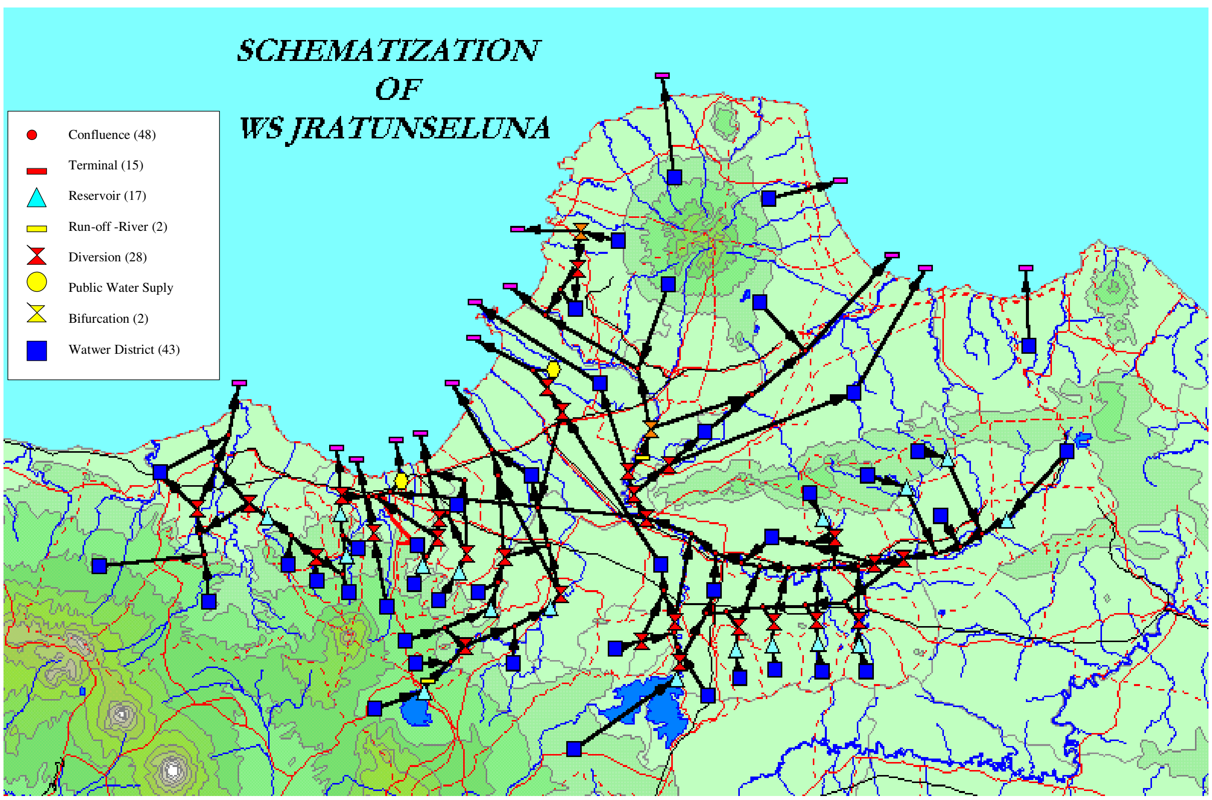

Figure 5: Schematization of the water balance

Irrigation represents a major activity in the basin, using by far most of its water resources. In general, efficiency of water use in irrigation is low (40 to 50 %). Table 2 presents the total present and projected cultivated land in the basin. The cultivated area will be influenced by a strong urbanization rate in some parts of the basin.

Type of cultivation	Cultivated area (ha)	
	Base case (2000)	Projected (2025)
Technical irr.	191,078	178,566
Semi-technical irr.	61,037	53,915
Rainfed	130,446	130,446
Total	382,561	361,830

Table 2: Cultivated area Jratunseluna basin

Sofar irrigation has developed to the extent that all irrigable land has been brought under production. Water availability forms a major constraint for further (water related) development in the basin. It is also the cause of a reduced (agricultural) productivity in drier parts of the basin. Further development of agriculture in line with the emphasis on agricultural development, as base line for the region (country), will require therefore full attention to the improvement of water availability. A most effective strategy to implement improvements in water availability should be determined for the basin and due account should be taken of the changing spatial development.

The analysis for such optimization is presented in Figure 6. There are primarily three routes (as well as combinations thereof) which can be followed, viz

a) increasing water use efficiency in the irrigation process (demand management measure),
b) development of new sources of water supply for irrigation (supply oriented measure), and
c) adapting the (future) cropping pattern to include less water consuming crops (demand management measure).

Option c) forms part of an overall desired change in future agricultural production, such option can then be considered as scenario's in the present analysis for the water sector.

Important information is then to identify the most effective strategy to increase water availability to agriculture, viz increase efficiency of irrigation water management or implement extra reservoirs or both.

Because irrigated land is limited improvements have to be realized through an increased irrigation intensity. Repeated simulations with the basin water balance model (Ribasim) were carried out to determine a maximum irrigation intensity for both potential strategies. For both a diversification scenario into non-rice crops was also considered. For adaptation of the cropping pattern a maximum irrigation intensity of 250 % has been considered as a realistic maximum in perspective of the present agricultural practice.

Two strategies have then been tested for their effectiveness in generating (agricultural) growth: an increase in the efficiency of irrigation water management and implementation of extra reservoirs. They have been considered to improve irrigation water supply in the basin and so to increase the amount of crop.hectares which can be irrigated. For both sub-strategies a diversification scenario to non-paddy crops is adopted.

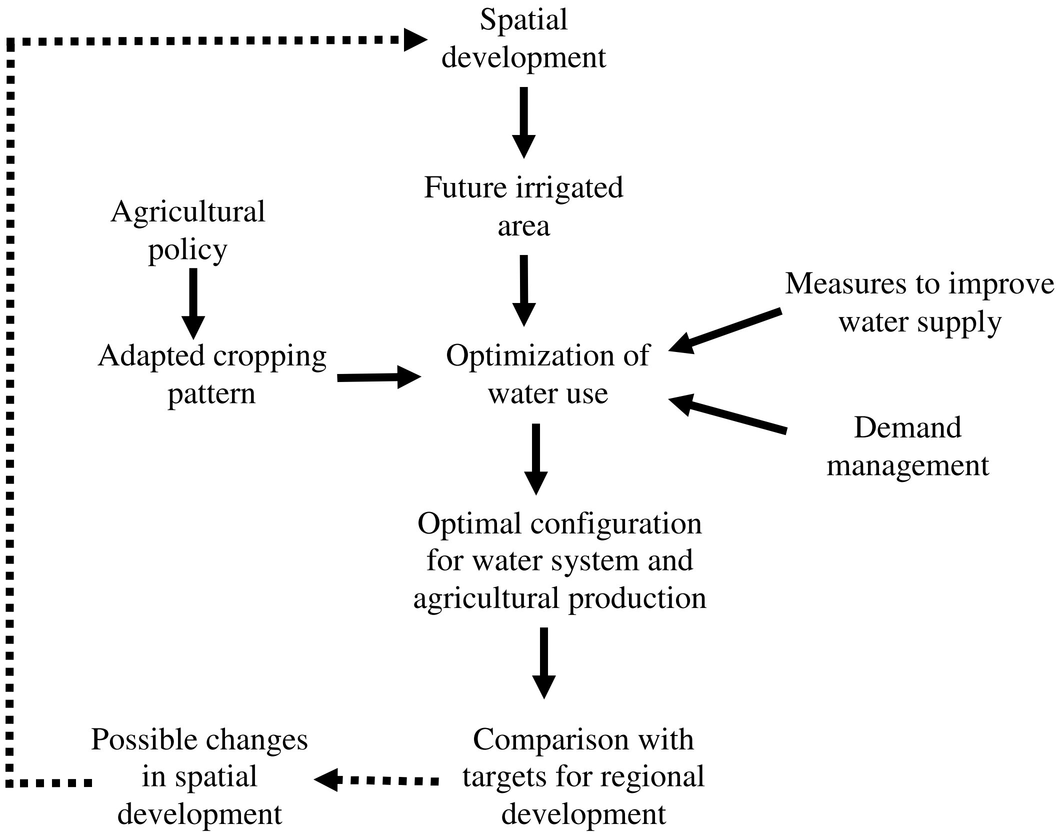

Figure 6: Role of spatial development in optimizing water system in the Jratunseluna basin

Realization of a maximum development potential for the basin consisting of an improved irrigation water management **and** extra reservoirs has also been analyzed. For such case little extra irrigated crop.has can be realized because the potential becomes limited by the combination of limited irrigated land and its maximum irrigation intensity. Further expansion of water availability beyond the expansion through efficiency improvement should only be considered if agricultural practice can absorb the extra water with a higher maximum intensity.

The results from the simulation analysis were used in an economic analysis for both strategy options. Table 3 presents a comparison of the effectiveness of investment; investment in improved irrigation water management is clearly much more effective.

Strategy Option	NPV generated for each BRp of investment (BRp)
Improved irr. w. management	1.26
Extra reservoirs	0.14

Table 3: Comparison of the effectiveness of the two strategy options for growth in irrigation

It can be concluded that important variables for an optimized (irrigated) agriculture production are the future irrigated area (linked to spatial development in the region), agricultural strategy (crop diversification) and water demand management (improved irrigation efficiency).

4.2 Zoning for erosion control

Erosion and associated sediment loads in rivers is found to be at the origin of, or is contributing to , several problems in the basin and even prohibits some potential future development. Sediment loads in the rivers are much higher than average over Java
The large sediment loads cause high O&M costs for downstream irrigation areas and floodways. Some of the potential future infrastructure developments have been evaluated as infeasible (e.g. Dolok, Jragung barrage) because of the large sedimentation.
In summary, erosion appears an important issue for sustained development of the basin.

Using the LREP II mapping, and following their classification of erosion sensitive areas, an estimate has been made of the extent of erosion sensitive areas in WS Jratunseluna. Figure 7 presents the location of such areas and their classification.

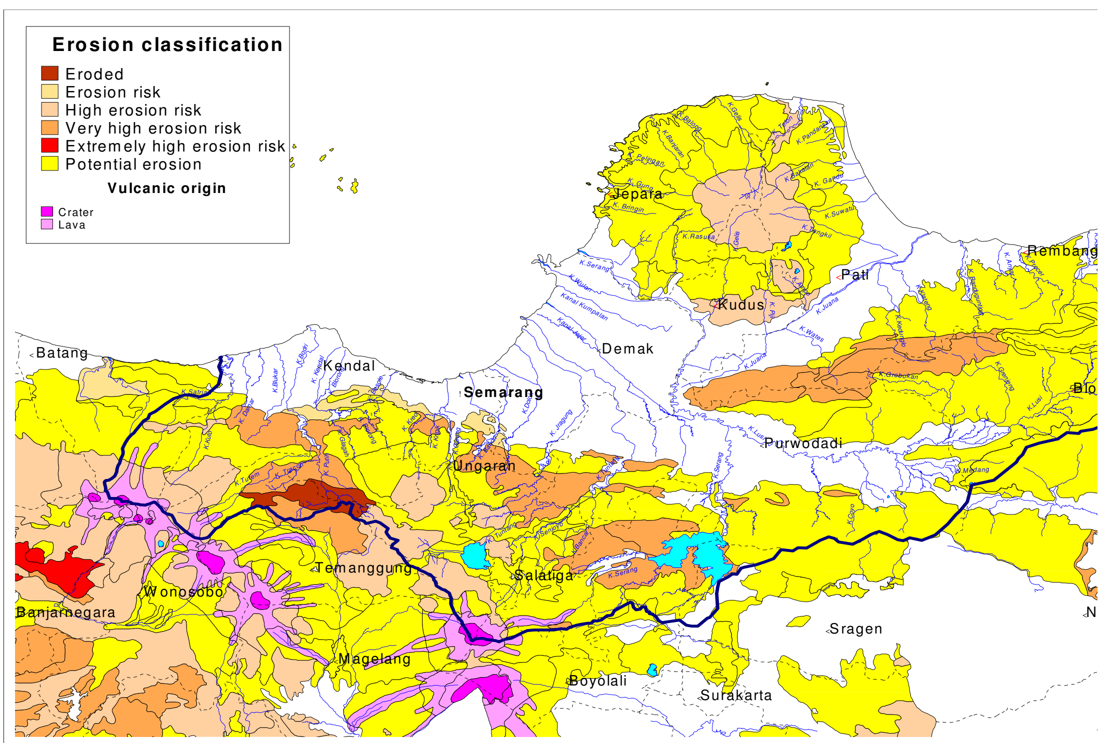

Figure 7: Classification of erosion sensitivity (LREP II)

The strong erosion sensitivity indicated in the upstream parts of the Jragung and Tuntang rivers explains the origin of their high sediment load.

A particular zoning for erosion control was derived including the sensitive areas with classification “high erosion risk” or higher. A field analysis of a trial area (MPW, 1999), provided an estimate of the effect of erosion on local (agricultural) production capacity as well as an estimate of costs for (small) infrastructure and re-greening measures, and provision of extension assistance. The benefits from conservation of this zone are summarized in Table 4: those refer to an improved production value of the conserved area (otherwise lost production value) and reduced maintenance for downstream irrigation areas and floodways.

River	**Water district (code)**	**Area (LREP II) (ha)**	**Impacts**		
			Floodway sedimentation (million m3)	**Irrigation maintenance (ha)**	**Sedimentation of reservoirs or lakes**
Serang	3100	18939	-	-	Kedung Ombo
Tuntang	2220	13583	7.48	32877	Glapan barrage
Jragung	2310,2320	5413	5.45		Jragung barrage
Blorong	1230, 1220	1986	1.6	4408	
Bringin	1300	1525	0.35	737	
Dolok	2510	2661	2.59	2826	Dolok reservoir
Babon	2520	3027	0.83	174	
Kreo	2720, 2730	624	-	-	Jatibarang res.
Garang	2710	1531	0.87	-	
Total		49289	19.17	41022	

Table 4: Estimated impacts of watershed Management on downstream water systems (MPW, 1999)

A cost-benefit analysis for this erosion zoning indicated a very high return (EIRR) of 34%. Such conservation strategy had the highest ranking among the set of strategies to further develop the river basin (MPW, 1999). Erosion and its control represent a complex process with widely ranging- and spatially distributed costs and benefits. The above analysis could only be made on the basis of several sources of information and an overall limited accuracy. Nevertheless the analysis points to an attractive investment and in particular illustrates the basic methodology for derivation of zoning: the zoning should be such that a sufficient return can be obtained from implementing the zoning.

For the above case it may be considered in a further attempt to optimize the conservation zoning by expanding the zoned area; incremental costs and benefits should determine if this is a better strategy.

5. CONCLUSIONS

For an anticipated strong change in future land-use it will be essential to be able to

- resolve (anticipated) conflicts in the use of space,
- determine demands in a pro-active planning of infrastructure to deal with the strong changes, and
- to deal with conservation which will be necessary to protect land, water , and environmental resources, which will come under increasing pressure .

A sketch has been given of the role of spatial modeling of land-use as part of preparation of a spatial plan and input to sectoral analysis, in this case the water sector.
An important application of such modeling is to test the impact of conservation plans and in particular the consistency with other development plans (housing, industry, agriculture, …). An essential part in the spatial model is the identification of the drivers for change in land-use.

The Jratunseluna case illustrates the intricate relationships between space- and water resources development: spatial projections are essential to establish the demand side in the planning of water resources development.

A main challenge will be to prepare conservation plans, zoning and associated regulations, for the different water resources aspects such as erosion and protection of a favorable runoff pattern (peak/low flow ratio).
As illustrated for the Jratunseluna erosion problem preparation of such zoning should be based both on an analysis of the physical process allowing to appreciate/rank the (critical) condition of the of different areas versus the value (or reduced damage) of the conserved water resources.

It can be observed that the derivation of conservation zoning (for example for erosion) is a complex task involving widely ranging - and spatially distributed costs and benefits.

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