INTEGRATION OF RS/GIS FOR SURFACE WATER POLLUTION RISK MODELING. CASE STUDY: AL-ABRASH SYRIAN COASTAL BASIN

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ABSTRACT:

Recently the topic of the quality of surface water (rivers – lakes) and the sea is an important topics at different levels. It is known that there are two major groups of pollutants: Point Source Pollution (PSP) and non-point Source pollution (NPSP).
Historically most of the surface water pollution protection programs dealing with the first set of pollutants which comes from sewage pipes and factories drainage.
With the growing need for current and future water security must stand on the current reality of the coastal rivers basin in terms of freshness and cleanliness and condition of water pollution.
This research aims to assign the NPS pollutants that reach Al Abrash River and preparation of databases and producing of risk Pollution map for NPS pollutants in order to put the basin management plan to ensure the reduction of pollutants that reach the river.
This research resulted of establishing of Databases of NPSP (Like pesticides and fertilizers) and producing of thematic maps for pollution severity and pollution risk based on the pollution models designed in GIS environment and utilizing from remote sensing data.
Preliminary recommendations for managing these pollutants were put.

1. Introduction

Recently, increasing public awareness about water quality is a major trend. It is well known that Point Source *(PS)* as well as Nonpoint Source *(NPS)*, or diffuse, sources of pollution are recognized to be the leading causes of water body pollution. PS loading originates from confined areas, such as discharge pipes in factories or sewage plants. NPS loading is carried by storm water runoff and percolating water draining residential, commercial, rural, and agricultural areas where many everyday activities add polluting substances to the land. Historically, most pollution control programs have initially dealt only with PS pollution; however, all over the world and for several decades, a large percentage of water pollution has been recognized as originating from many NPSs (Novotny 1999). Typically, in less developed countries, PSs such as sewage from urban areas and NPSs such as sedimentation from deforestation or agricultural practices are the main components of pollution. In developed countries, runoff from agriculture and urban sources are the leading causes of nonpoint pollution (Luzio, et al., 2004).

The control and management of water quality, particularly for impaired streams where NPSs are the overwhelming sources, would require outrageously expensive monitoring activities. The modeling alternative requires the description and understanding of several hydrologic phenomena with intrinsic spatial and temporal variation. Mathematical, hydrology-based, distributed parameter simulation models and GIS technology provide a potential synergy that appears to be the key feature for an effective under-standing and interpretation of these complicated hydrologic processes connected with water quality assessment. There are diverse elements promoting the development of such systems for water resources applications (Wilson et al. 2000).

In the case of availability and quality of supporting datasets provide convenient descriptions of important hydrologic variables that are related to chemicals, soils, climate, topography, land cover, and land use.
These elements will ultimately increase the reliability of decision support tools on a watershed scale, the hydrological unit where NPSs and PSs are required to be correctly factored into an effective management system, as all human and natural activities upstream have the potential to affect water quality and quantity downstream.
Agricultural pollution is difficult to monitor since all pollution sources are non-point in nature. The non-point source pollution (NPSP) has long been a major concern all over the world. The USEPA noted in 1990 that routine agricultural activities were responsible for more than 60% of the surface water pollution problems in the US. The importance of agricultural NPSP control has frequently been emphasized in the reports of Environment Canada and Canadian Environmental Assessment Agency even related figures are not available.
Successful management of agricultural NPSP requires an understanding of the pollutant transport mechanisms from runoff to surface water. These mechanisms are very complex, and quite a few factors such as hydrological, topographical, chemical transport, soil-type and land use conditions are involved in determining NPSP process.

The primary requirements for GIS in NPSP modeling can be identified with respect to the features of the modeling work (Hamlett et al. 1992; Engel et al., 1993; Tim and Jolly, 1994; Srinivasan and Engel 1994; Srivastava et al., 2001; Luzio et al. 2004; Yaghi et al. 2012, 2013). As suggested by previous studies on agricultural NPSP with GIS application, a GIS for this area should be capable of performing complex manipulation and analysis of spatial and non-spatial data for the development and preparation of data inputs to models, providing the linkage mechanisms between models having different spatial representation, facilitating the conversion and standardization of data in digital form of different scales and coordinate systems, and enabling post-simulation analysis through graphical display and spatial statistical summaries that facilitate explanation of modeling results.

NPSP modeling is concerned with the movement of pesticides and nutrients, as well as soil erosion. As described by Engel et al. (1993) for agricultural watershed modeling, distributed parameter models incorporate the variability in landscape features that control hydrologic flow and transport process, and thus, are potentially more realistic.
The objectives of this study are to:

1. Designing a GIS Model for monitoring the NPSP from the agricultural sources like fertilizers and pesticides.
2. Establishing the data set in a format suitable to be entered to the GIS model easily.
3. Run the model and get the agricultural pollution risk map for the basin in the year 2011 as the land use map is for this year.

2. Study Area

2-1- Location
Al Abrash river basin is one of the Syrian Coastal Zone Basins. It is approximately 45 kilometers long and 5 to 10 kilometers wide starts from north east in the mountainous area and ends in the South West at the sea line. Al Abrah Basin includes parts of three Governorates (Tartous, Homs and Hama). This area encompasses about 235 square-kilometers.

2-2- Geomorphology
The Basin is geomorphologically divided into three Parts (Figure 1):

- Upper basin: is a mountainous area, with altitude of 1100 -400 m
- Middle Basin: is the hilly area, with altitude of 400 – 100 m
- Lower Basin: plain area, with altitude less than 100 m

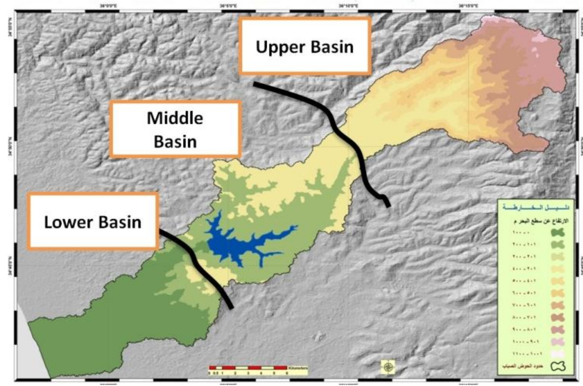

Figure 1: Geomorphology of the study area

2-3- Climatology
The climate in the study area is a Mediterranean climate. The participation is between 700 and 1400 mm per year. The average temperature is 13 centigrade degree for the coldest month and 28 centigrade degree for the hottest month.

2-4- Land use
Arable land is about 65% from the total basin land followed by the forest land with 21%, urban 5%, water bodies 5% and others 4%.
The arable land is classified as: olives plantation 57% – citrus 7% – green houses 4% – crops 25% - apple 7%
The fertilizers and pesticides are applies in the arable land are illustrated in table (1).

Land use	Fertilizers kg/donom*	Pesticides kg / donom *
Olives	**60**	**0.25**
Citrus	**125**	**0.3**
Green houses	**120**	**1**
Crops	**65**	**0.75**
Apples	**80**	**1.5**

Donom is 0.1 hectar
Source: Tartous Agricultural Directorate – Plant Protection Section (2012)

Table (1): Average Fertilizes (Phosphorous, Nitrogen and Potassium) and Pesticides Loads by Land Use in Al – Abrash River Basin (kg/Donom)

3. Materials and Methods

3-1 Materials:

- Satellite images (rapid eye 2011 – IKONOS 2012)
- DEM (30 m resolution)
- Topo maps 1/25000
- Arc/GIS
- ERDAS
- GPS

3-2 Theory

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Maas et al. (1985) show that areas of severe soil loss are often the critical areas for agricultural non-point source pollution. Schauble (1999) mentions that erosion includes not only the transport of sediment particles but also the transport of nutrients and pollutants. Both mechanisms depend on the amount of surface runoff and are therefore linked together. Both processes can only be lessened by reducing the surface runoff in favor of ground water infiltration. Due to this inseparability of both processes, erosion models can be used to find critical areas of non-point source pollution also. For modeling erosion, many models have been developed. De Roo (1993) gives an overview of some important models: universal soil loss equation (USLE; Wischmeier and Smith, 1978), revised USLE (RUSLE; Renard et al 1991), modified USLE (MUSLE87; Hensel and Bork, 1988), areal non-point source watershed environment response system (ANSWERS; Beasley and Huggins, 1982) and agricultural non-point source pollution model (AGNPS; Young et al., 1987). Many of the newer models are derived from the basic USLE of Wischmeier and Smith (1978). This equation is the result of empirical long-term runoff studies on test fields in the USA. It estimates the long-term annual soil loss in [tons/ha]. The formula consists of multiplied factors and is as follows:

A = R*K*L*S*C*P

The factors are:
A: result: mean long-term annual soil loss in [tons/ha]
R: rain and surface runoff factor
K: soil erodibility factor
L: slope length factor
S: slope steepness factor
C: vegetation cover factor
P: erosion protection factor

3-3 Methodology

GIS was used to:

- produce Hydrology maps using ARC/HYDRO.
- produce rainfall map and pollution map using Geo-statistical analyst
- produce SLOPE & ASPECT using SPATIAL ANALYST & 3D
- NPSP modeling

RS (satellite images) was used to: produce Land Cover / Land use maps.

GPS was used to: assign some important locations (environmental points, soil measurements……)

In this research we performed rough analyses to reveal critical erosion and non-point source pollution areas using the advantages of a GIS, and used a modified USLE model (Sivertun et al., 1988). That model combined four factor maps by simple raster value multiplication to produce a risk map. Weights for every factors were established based on the literature review of similar researches and the experiences of the researcher (Yaghi et.al., 2012- 2013). The formula used is as follows:

P = K*S*W*U

The maps are:
P: product map, showing the risk of erosion and pollution
K: soil factor map
S: slope factor map
W: watercourse factor map
U: land use factor map

In contrast to the original USLE, the product map of the modified USLE does not give information on the actual sediment or pollution load, but it allows one to find places with a high risk of erosion or influence on surface water quality in the investigation area.

Table 2 shows the values of the factor maps. The model has been chosen for this work because it gives a fast overview of the critical areas, which can later be analyzed more profoundly with a more sophisticated technique. An advantage is the time and cost saving. Updating is also easy: if more accurate maps are available or the land cover changes, it does not influence the other factor maps. The model can be recalculated easily after changing one factor map. Thus, the model can be used for long-term studies within the scope of sustainable development (Schein and Sivertun, 2001 ; Yaghi et al. 2012 -2013). It is illustrated in Figure (2) and table (2).

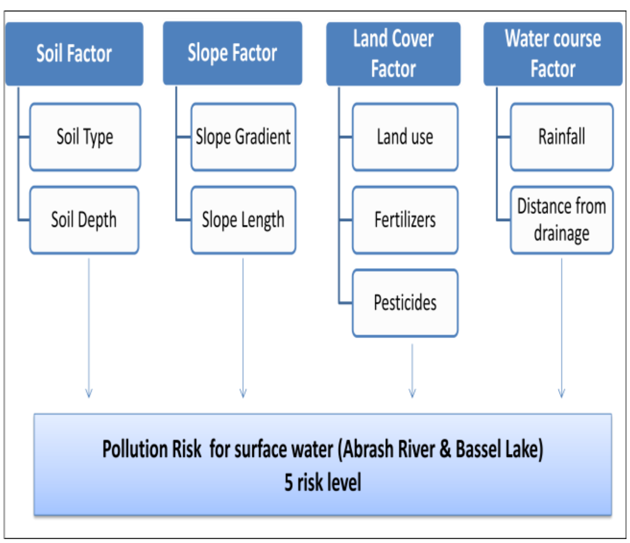


Figure (2): Flow chart of the pollution risk modeling

Weights	Classification	Layers	Factor
30	**very sloppy Mountainous Soil**	**Soil Type**	**Soil**
25	**Light and moderate sloppy land soil**		
20	**Sloppy hilly shallow soil**		
18	**Undulating land soil**		
15	**Light undulating land soil**		
12	**Upper plateau soil**		
10	**Hilly soil**		
8	**River bed soil**		
6	**Valley soil**		

4	Alluvial soil		
2	Plain soil		
1	Local low soil		
1	URBAN		
1	URBAN	Soil Depth	
2	Alluvial soil		
4	More than 100 cm		
6	50 – 100 cm		
8	25 – 50 cm		
10	Less than 25 cm		

Weights	Classification	Layers	Factor
1	0 %	Slope Gradient	Slope
2	1 – 3 %		
4	3 – 5 %		
8	5 -8 %		
13	8 – 11 %		
21	11 – 14 %		
30	> 14 %		
1	0 – 6 m	Slope Length	
2	6 – 12 m		
3	12 – 18 m		
4	18 – 24 m		
5	24 – 30 m		
6	30 – 36 m		
7	36 – 42 m		
8	42 – 48 m		
9	48 – 54 m		
10	54 – 60 m		

Weights	Classification	Layers	Factor
0	Urban	Land use	Land cover / Land use
0	Water bodies		
20	Unused land		
30	Left agricultural land		
10	Green houses		
20	apples		
10	Citrus		
10	Olives		
5	Sandy beaches		
5	Forest		
15	Crops		
25	Treatment stations		
25	Queries		
25	Landfill		

Weights	Classification	Layers	Factor
1	Urban	Fertilizers Usage	Land cover / Land use
0	Water bodies		
9	Green houses		
6	Apples		
10	Citrus		
4	Olives		
1	Forest		
5	Crops		
1	Urban	Pesticides Usage	
0	Water bodies		
8	Green houses		
10	Apples		
3	Citrus		
2	Olives		
1	Forest		
7	Crops		

Weights	Classification	Layers	Facto r
2	800 – 900 mm	Rainfall	Water course factor
5	900 – 1000 mm		
8	1000 – 1100 mm		

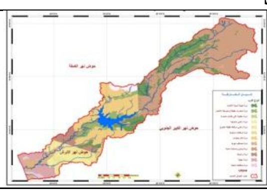
10	**1100 – 1200 mm**		
15	**1200 – 1300 mm**		
20	**1300 – 1400 mm**		
25	**1400 -1500 mm**		
30	**1500 – 1600 mm**		
0	**Drainage**	**Distance from Drainage**	
10	**1- 100 m**		
9	**200 – 100 m**		
8	**600 -200 m**		
6	**1100 – 600 m**		
3	**2000 – 1100 m**		
1	**More than 2000 m**		

Table 2: Factors and weights entered to the model of surface water pollution risk map

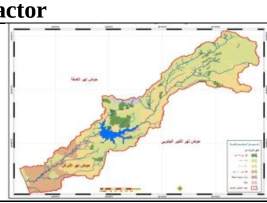
4. Results

Based on the results of multiplication of factor maps (Figure 3), we classified the results into five surface water pollution risk classes. Table (3) and figure (4) illustrate the result of this research.

Soil Factor

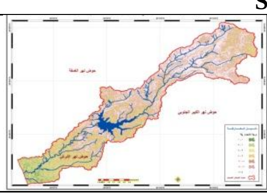


Soil Type

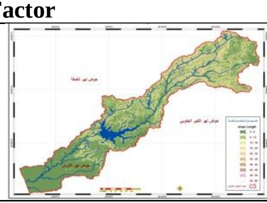


Soil Depth

Slope Factor

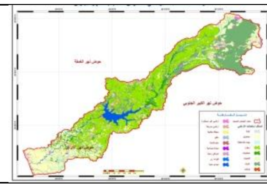


Slope Gradient

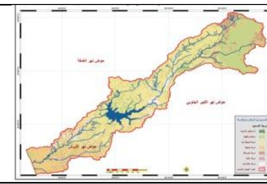


Slope Length

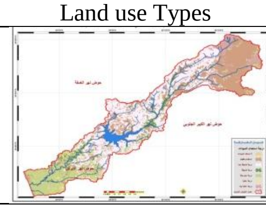
Land Cover /land use Factor



Land use Types

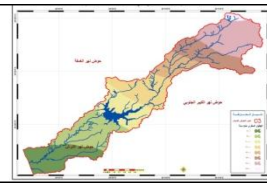


Fertilizers Application

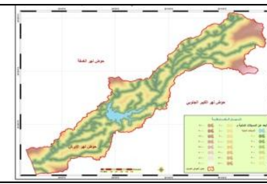


Pesticides Application

Water course Factor



Rainfall



Distance from drainage

Figure 3: Factors maps of the proposed model

	Pollution Risk Level	Weights multiplication	Area (m)	Percentage
1	Not Relevant	0	47516.5	20.28
2	Very slight pollution	Less than 5000	107747.4	45.98
3	Slight Pollution	5000 - 10000	18537.8	7.91
4	Medium Pollution	10000 - 25000	33177.9	14.16
5	High Pollution	25000 - 50000	15418.0	6.58
6	Very high Pollution	More than 50000	11917.4	5.09
			234314.97	100

Table 3: surface water pollution risk classes, areas and percentages

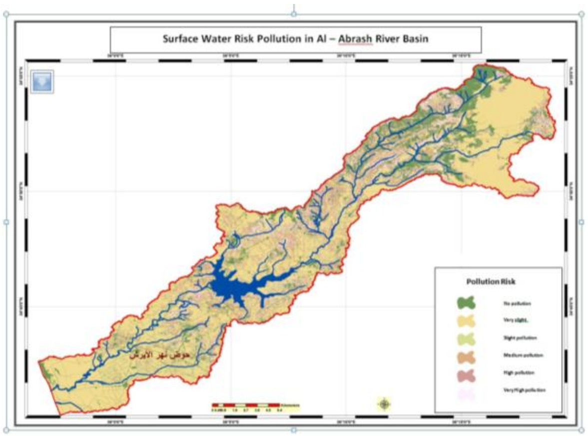


Figure 4: surface water pollution risk map:

5. Conclusion

In this paper, we presented and concluded the following:

- The powerful of GIS modeling for producing surface water pollution risk map of nonpoint source pollution on a watershed scale.
- The derived surface water pollution risk map can be updated every time we can get more accurate or updated land use maps.
- Based on the model applied, Al - Abrash Basin was divided into 5 surface water pollution risk classes. Locations, areas and percentage of every class were calculated.
- The method can be applied for all coastal rivers basins.
- GIS can also used to select the best locations for water analysis in order to know the concentration of the pollutants though the time (water monitoring plan).
- The result of such kind of research can be used in the integrated land management and in managing sedimentations, nutrients and pesticides measures in the coastal zone.

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