Hypsometrical Technique Automated as a Decision Support System, Assessment of Environmental Indicators in Loukkos Basin in Morocco

Ridouane Chalh, Zohra Bakkoury, Driss Ouazar, Moulay Driss Hasnaoui

Abstract - The primary objective of this current paper is to design, develop and automate an approach called the Hypsometrical Approach (HA). This approach automated and developed as a decision support system using environmental indicators for managing and planning water resources. It servers to analyze and to make comparison of various current and future scenarios of different quantifiable indicators for any consideration and for various socio-economic aspects. It is also used as a decision tool to improve or at least to preserve environment and natural resources. HA needs to draw its data from different sources like satellite images and watershed information system such as watershed characteristics including equipment infrastructures (Drinking water supply, irrigation system), transportation infrastructures (Roads, dams), natural resources (Water, soils, and vegetation), human activities (Agriculture, urbanization and industry) and different socio-economic factors (Demography). Globally in this paper the automation of this Hypsometrical Approach is divided into two main parts, the first part based on identifying and extracting data pixel by pixel from classified satellite images using python programming language, and the second part related to the development of a system allowing users to generate and visualize different curves called hypsometrical curves developed using Java programming language. We can combine any hypsometrical curve with arithmetic operations (addition, multiplication, subtraction and division) in order to assess some other indicators such as water resources, watershed storage capacities, vegetation, soils and forest potentials curves. Briefly, the objective of automating hypsometrical approach is to make efficient decision to improve the socio-economic level and enhance sustainable development.

***Index Terms*: Hypsometrical Approach (HA); Decision Support System (DSS); Image Satellite; Water Resources Management; Environmental Indicators; Hypsometrical curve.**

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I. INTRODUCTION

This work refers to our previous paper entitled "Big Data Open Platform for Water Resources Management" [1], where the conceptual architecture of a Big Data Open Platform used for supporting and managing water resources has been presented. This Platform has been designed to provide effective tools, and consists of nine blocks as follows: 1) Decision Support Tools, 2) Knowledge Based System, 3) Geographic Information System (GIS), 4) Big Data Analysis System, 5) Simulation Models, 6) Computation and Processing, 7) Communication System, 8) Search Engine and 9) Users Interface. In this paper, we will focus on the first block of the platform named Decision Support Tools.

This study reports on an automated approach called Hypsometrical Approach based on different quantifiable indicators. This approach analyses future situations and allows making prospects based on different socio-economical evolution scenarios [2]. The basic data needed for this approach are watershed characterization, embody geometry, morphology, geology, soil, and land cover/use.

Regarding the paper structure it organized as follows. Section I gives a definition of hypsometrical approach, aim and how it functions; section II illustrates the methodology by giving the conceptual architecture of each system used to automate this approach and also how it works technically; section III discusses about application, results and area of study, section IV concludes.

A. Hypsometrical Approach Definition

Hypsometrical Approach (HA) developed as Decision System Tool (DST), According to [3] DST is a computerized like as system that utilizes databases, models, and dialog systems to provide decision makers with timely management information and to interact with the system. Development of a DSS for facilitating water quality management is mentioned [4] [5].

Hypsometrical Approach used to analyze and to make comparison of diverse current and future scenarios of different environmental indicators for various socio-economic aspects. These environmental indicators are extracted from various sources such as:

- Satellite imagery analysis.
- Terrain dataset analysis.
- Water data related to hydrology.
- Statistics of socio-economic…

B. Aim of Hypsometrical Approach (HA)

The aim of HA is to facilitate decision making, especially in regards to improve sustainable development. In order to function, this approach needs to have access to an information system that contains data related to several aspects of a watershed, including:

- Watershed characteristics (Drinking water supply, irrigation…).
- Infrastructure (Roads, dams, socio-economic…).
- Natural resources (Water, soils, vegetation …).
- Human activities (Agriculture, urbanization and industry, fauna and flora…).

C. How Hypsometrical Approach Works?

In this section we explain how Hypsometrical Approach functions. We consider a basin X that contains watersheds and soils as example of environmental indicators, after extraction of data from this basin using classified satellite image as data source, there are other data like as : existent databases, files, DTM…etc. Afterwards we transform these data, using the system developed in section (system overview) bellow into different curves called hypsometrical curves. The objective here is to give to water system managers a possibility to make comparison with other curves in order to make efficient decisions as illustrated in Fig. 1 as example of comparison in this figure, we observe an excess of water above the altitude, but we observe a water deficit at the bottom.

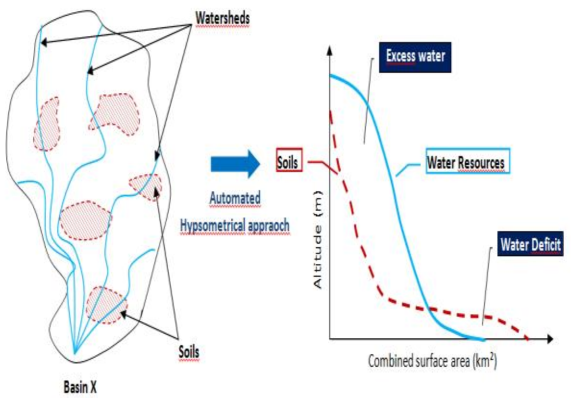

Fig. 1 : How Hypsometrical Approach Works

D. Study Area Overview

Our study Area is bounded by the Rif Mountain Range and the Atlantic Ocean (see figure below). The basin of Loukkos has a surface of 3 747 km^2 [6]. It includes several agricultural areas of great economic importance in Morocco. The main agglomerations of the basin are: Larache, Ksar El Kebir and Ouezzane.

Accordind to [6] Loukkos basin contains three large dams, Makhazine (700 hm^3), Dar Khrofa (480 hm3) and Loukkos Guard (4 hm^3, in the estuary).

Based on [7], the population of the area stands at 535 174 inhabitants (General Census 2004), of which urban population: 240 597 inhabitants, rural population: 294 577 inhabitants and farmers: 29 400.

Loukkos is characterized by a variety of lifestyles. The alluvial plain is intensely cultivated by very often modern techniques. Two forests limit this unit to the North and South. From the climatic point of view, this zone is homogeneous with respect to the rain received, although it increases inland and at altitude.

The Bas Loukkos Basin is the most developed natural area in the region, with good soils and abundant water and covering the alluvial clay plains and the sandy plateau of Larache. Soil types are diverse, and are composed of format. The figure Fig. 2 bellow illustrates satellite image and Fig. 3 his compatible Digital Terrain Model (DTM).

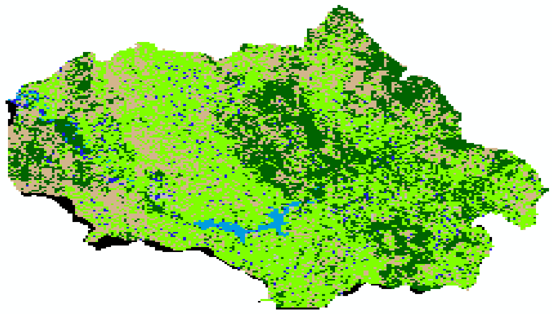

Fig. 2 : Satellite image of Loukkos basin

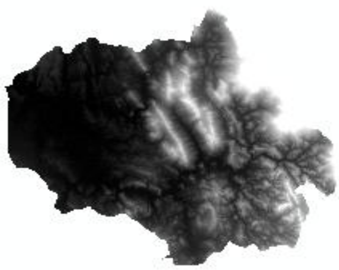

Fig. 3 : Digital Terrain Model (DTM) of Loukkos basin

II. METHODOLOGY

The conception and automation of this approach is based on computation of the hypsometrical distribution, indicators related to environment and future sustainable development. Afterword different scenarios based on this computation are built.

The objective is to improve the socio-economic level and living standards. We can put any hypsometrical distribution together to assess watershed potential, fit any need, measure the impact, analyze the interaction between indicators, and finally check their relations within the watershed [2].

The current research emphasis on automating hypsometrical approach as decision support system. The structure of this automation divided into two fundamental parts, the first part concerns data identification and detection from classified satellite image using python programming language, and the second concerns exploitation of first part results and implementation of our hypsometrical approach using Java programming language.

Before giving more details about system overview, it is useful to give some literature about satellite imagery domain. Satellite imagery plays a very important role in providing geographical information. We have two categories of satellite images; classified and unclassified. According to [8] the classification process consist to regroup pixels values of any image in different significant class. There are a lot of techniques and methods to classified satellite images; it can be classified into three kinds of methods such as: Manual, Hybrid or Automatic [9]. In our case we consider the satellite image as classified before using automatic method.

A. System Overview

A.1 Part I: Extract data from satellite image using python programming language

In this first part we develop a program using python programming language to identify, detect and extract data from satellite image. The goal of this work is to prepare data from classified satellite image in order to automate our approach. To do this, we choose a site located in the north of Morocco presented by Loukkos basin as a case study. We first consider satellite image classified into classes: watercourses, bare soil, crop lands, forests…etc. Afterward, we read the image in order to extract data pixel by pixel in the whole image, and then we identify a position of X and a position of Y in order to extract data of each pixel represented by his identifier (Module I in Fig. 4).

The second step of this part is to extract position Z that represents the altitude. To do this we should superpose the DTM (Digital Terrain Model) of Loukkos basin on satellite image to extract the position Z (Module II in Fig. 4 appropriate to [X, Y] position.

The third step of the same part (Module III in Fig. 4) consists of calculating combined surface area calculated by multiplying satellite image resolution and number of pixel of each class.

Combined surface area = Number of pixels × Image resolution

At the end we save automatically all these extracted data into database. A qualitative evaluation of these results has oriented us in the choice of the parameters to be used in the second part of this paper. Technically, the figure (Fig. 4) bellow illustrates how this first part works.

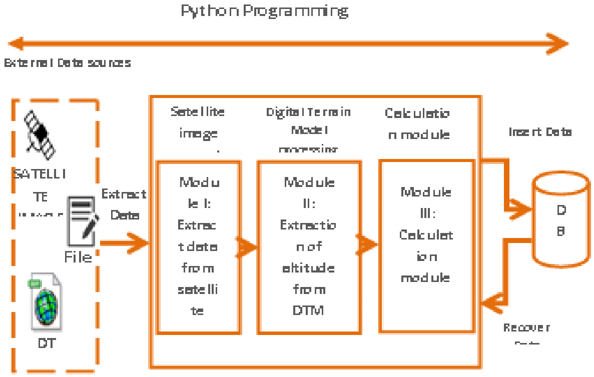

Fig. 4 : Identification and extraction of data from satellite image of Loukkos basin using python

This part is also used in another work that belongs to us to estimate the potentiality of environmental indicators using regression analysis within the watershed Loukkos, Tangerois and Mediterranean Coastal Basin in Morocco [10].

A.2 Part II: Automating Hypsometrical Approach System using java

This second part is the continuity of the first part above (Part I); we have implemented a hypsometrical approach used to analyze and to make comparison of various current and future scenarios of different quantifiable indicators for any consideration and for various socio-economic aspects. It is used to make choice of ways to improve or at least to preserve environment and natural resources.

Technically a special effort has been granted to standardization of input/output parameters when developing this system to automate Hypsometrical Approach as explained in this second part.

The conceptual structure of our system to automated Hypsometrical Approach as shown in Fig. 5, which consists of four modules as follow: Import Module, Graph Configuration, Graph Generator, and Visualization Interface.

1) **Import Module:** used to import data from database of the first part, the goal of this module is to integrate a tool to retrieve and load data. These data is presented either in MySQL DBMS format, which can be used directly by other following modules.
2) **Graph Configuration Module**: is connecting to the rest of the system. Here we can add more axes and other graph elements. And also connect the graph elements.
3) **Graph Generator Module:** is a very simple graph generator that generates a graph using data from database system. This module has been developed with a powerful combination between JFreeChart and Cewolf libraries using Java in order to generate dynamically the hypsometrical curves.

4) The fourth module called **Visualization Interface**; it provides users with capabilities of communicating with the system. It helps users formulate the problem, presenting results, graphics and visualizing data. It also allows users to compare the effects of different current and future management scenarios and make choice to preserve the environment and natural resources, which can be seen in Fig. 5 bellow.

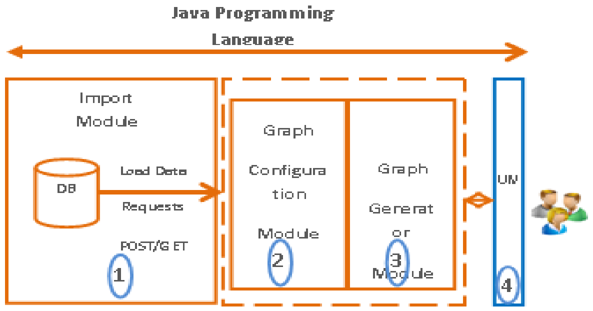

Fig. 5 : Conceptual architecture of Automated Hypsometrical Approach System

To achieve the development, the main application in our system has been carried out using MVC (Model, View and Controller) design pattern.

III. Results, Application and Discussion

All components of the main application have been coded and written in Java. Java is an effective programming language extensively used nowadays to develop dynamic web projects;

A. Data of studied parameters

The following tables: Agglomeration (**72 988 rows**), forests (**1 058 287 rows**), bare soil (**916 464 rows**) and crop lands (**1 822 493 rows**) represent the results obtained by applying Part I as explained in (Figure 4 A.1) among these parameters (id pixel, position X, position Y, altitude (z) and combined surface area of each class in satellite image). Table 1 illustrates data of studied parameters, in our case study twos parameters used: altitude and combined surface.

Table.1Agglomeration, Bare soils, Crop lands and Forests studied parameters data

Agglomeration		Bare soils		Crop lands		Forests	
altitude	surface	altitude	surface	altitude	surface	altitude	surface
0	0.00891	0	0.0738	0	0.07173	0	0.08757
2	0.00909	2	0.07407	2	0.07227	3	0.08775
3	0.00945	3	0.07434	3	0.07308	4	0.08955
…	…	…	…	…	…	…	…
209	3.30687	226	49.6036	916	163.149	1072	90.5004
210	3.31659	227	49.6844	923	163.182	1079	90.6258
211	3.32928	228	49.7648	925	163.192	1084	90.7095
212	3.34296	229	49.8494	944	163.286	1087	90.7567
…	…	…	…	…	…	…	…
1129	6.56856	1631	82.4814	1648	164.024	1672	95.2455
1147	6.56865	1640	82.4815	1652	164.024	1675	95.2456
1157	6.56874	1654	82.4817	1654	164.024	1678	95.2457
1177	6.56883	1654	82.4817	1662	164.024	1678	95.2457
1193	6.56892	1676	82.4818	1678	164.024	1681	95.2458

B. Assessment of Some Selected Environmental Indicators in Loukkos Basin

To illustrate the purpose of this automated hypsometrical approach, some representative curves are shown for some selected environmental indicators [11] such as:

- Assessment of agglomeration.
- Assessment of forests.
- Assessment of bare soil.
- Assessment of crop lands.
- Assessment of zones covered by forests, crop lands and bare soil.

We can use the hypsometrical approach to evaluate watercourses [12] at different elevations. In order to show further how water resources match the needs of available soils [13], we are interested in this following hypsometrical approach on distribution of bare soils [14]. In addition we are interested also in the environmental aspect of crop lands as illustrated in Fig. 6 and 7.

The basic indicator for vegetation [13], is the distribution of the surface covered by each kind from the upstream to downstream of the basin; in our case study we take forest and agglomeration as example of environmental indicator of vegetation as shown in Fig. 8 and 9.One of the main objectives of our automated hypsometrical approach is to identify a list of sites for storing water represented by the potential sites of dams [15].

This hypsometrical approach can also be used to evaluate the distribution of each vegetation species in basin like as zones covered by forests and bare soils as illustrated in Fig. 10.

On the other hand we can combine any hypsometrical curve with arithmetic operations (addition, multiplication, subtraction and division) in order to assess potential needs for example multiplying one value of the hypsometrical curve for each species with the yield which corresponds to the targeted analysis.

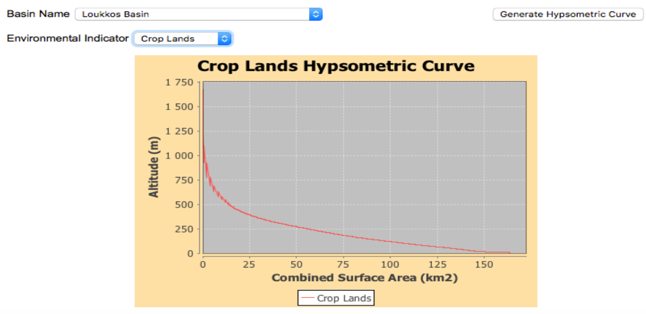

Fig. 6 : Assessment of bare soil hypsometrical curve

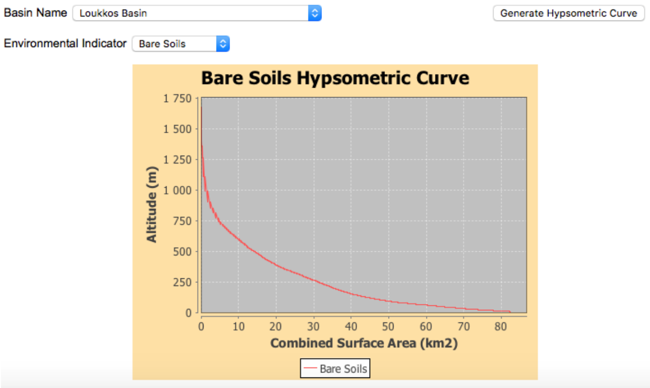

Fig. 7 : Assessment of crop lands hypsometrical curve.

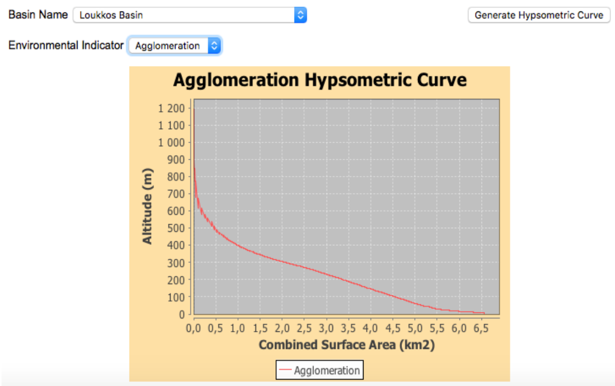

Fig. 8 : Assessment of agglomeration hypsometrical curve.

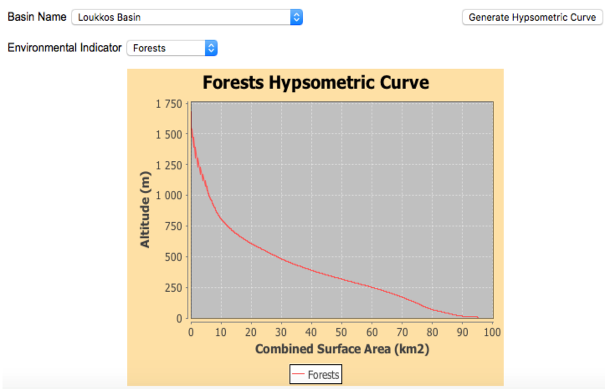

Fig. 9 : Assessment of forest hypsometrical curve.

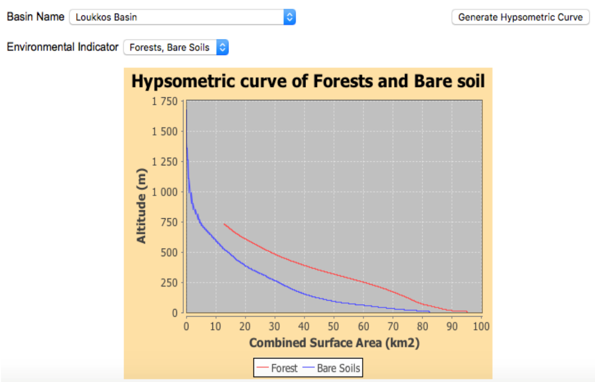

Fig. 10 : Hypsometrical distribution zones covered by bare soils and forests.

IV. CONCLUSION

The paper's primary objective has been focused to automate Hypsometrical Approach as a decision support system, integrating environmental indicators in Loukkos basin. The paper first gives an overview of hypsometrical approach developed and integrated for rational planning and management of watersheds. The paper second focused on the system conceptual structure overview. The paper last presents methodology and implementation of our system, choosing Loukkos basin as experimental site.

In our study case, we have automated this approach to allow optimal solution for sustainable development in order to improve and /or to preserve the environment.

For all the factors within the basin and the interaction between them, our automated hypsometrical approach is able to make different right decisions and also to make comparison of diverse current and future scenarios of different quantifiable indicators for any considerations and for various socio-economic aspects.

Moreover, the optimal solution for rational planning and management are made with the hypsometrical approach. It can be performed for a small sub-basin as well as the whole basin like as in our study case Loukkos, Tangerois and Mediterranean coastal basin.

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