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FINDING AND DESIGNING DAMS USING GIS AND MULTICRITERIA DECISION MAKING

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ABSTRACT

Design of the dam passes in several stages beginning by exploratory studies and ending Select design dimensional of the dam. The exploratory stage studies are considered of the most important stages of the design of the dam to ensure selection of the optimal location for the dam and necessary detailed requirements to begin design of parts Dam. Suitable site for dam is considered as a multi-faceted challenge. The main objective of this study is to develop a multi-criteria decision algorithm capable of selecting the optimum dam site and its main specifications when planning to design dams taking into consideration all available data in a short time and with high flexibility. The algorithm is composed of three stages of analysis. The first stage is to generate a suitability map for dam site inside the entire study area while the second stage getting the optimum site among the highly suitable sites found in the first stage. The third stage is design of the cross section of suggested dam.

To achieve this framework, a GIS-based MCDM tool for dam site selection is developed as a toolbar in ArcGIS9.3 environment. In this research, we suggested to build dams on Kneceh branch. The results show that GIS-MCDM in dam site selection would simplify the definition of decision strategies and facilitate an exploratory analysis in short time and less effort.

KEYWORDS: Dam site selection; Geographic Information System (GIS) ; Analytical Hierarchy Process (AHP) ; and Ordered Weighted Averaging (OWA) ; MCDM.

1. INTRODUCTION

A dam is a structure that is built across a river or stream for several purposes, such as irrigation, water supply, flood control, electrical power production, navigation through difficult rivers, recreation, and for recharging the ground water reservoir.

Engineering design of dam is an important issue from the viewpoint of safety and economy of construction cost. Therefore, designing a dam essentially means the determination of cross sectional parameters of the dam. Of course, the determination of materials and methods to be used in the construction of the dam is very essential for designing the dam.Building a new dam is difficult in recent years due to the interaction of many factors such as topography, geology, foundation conditions, hydrology, earthquakes, availability of construction materials, economic, environment, and social effects. [1]

There are several factors that affect dam design such as the type of material and availability, dam site, valley shape, climate, foundation … etc.[1]

Over the past few years, Geographic information systems (GIS) was an important tool for providing a comprehensive means of managing and handling water resources data in a way that cannot be accomplished manually. Recently multicriteria decision making (MCDM) technique is tools employed to solve these problems. GIS-based MCDM used as procedure for determining the sites of dams. Most of the published research on this specific topic either used the Analytical Hierarchy Process (AHP) or GIS-based AHP for choosing suitable sites for a specific dam. Although AHP is widely used, but it gives one scenario, which needs to be adequately handled. While Ordered Weighted Averaging (OWA) gives several scenarios.[1]

The goal of the paper is to find sites of supply and irrigation dam by using GIS-based AHP-OWA Approach which allow decision-makers to define a decision strategy on a continuum between pessimistic (risk-averse) and optimistic (risk-taking) strategies.

Several researches are made to identifying the most appropriate site for a dam. For example,: Boldaje et al. (2011) assessed the site location of a small earth dam using GIS and

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MCD. They considered as factors: slope percentage, boundary to river (boundary out of 10m to river), geomorphologic units and geological features, economical factors (Resource materials, boundary to road, and boundary to residential area). They combined the map using overlay to get the dam site suitability map [2]. Johannes and John (2011) employed Multi-criteria decision analysis for reservoir site selection from four alternative sites in Colorado, considering geological hazard, pipeline cost, evaporation Forests as criteria in decision [3]. Soleyman et,al. (2013) used the AHP method to compare between three sugested type of dams according to cost, geology, and building material criteria [4]

The general methodology steps for dam design in this search contains three stages as shown in Figure (1): [1]

- **i.** First stage is generating suitability map of dam sites inside the entire area using general criteria.
- **ii.** Second stage is finding the optimum dam site from suitability map using specific criteria.
- **iii.** Third stage is to design the cross section of the optimume dam depending on valley specification, and study the stability of suggested cross selection to obtain the minimum stability requested.

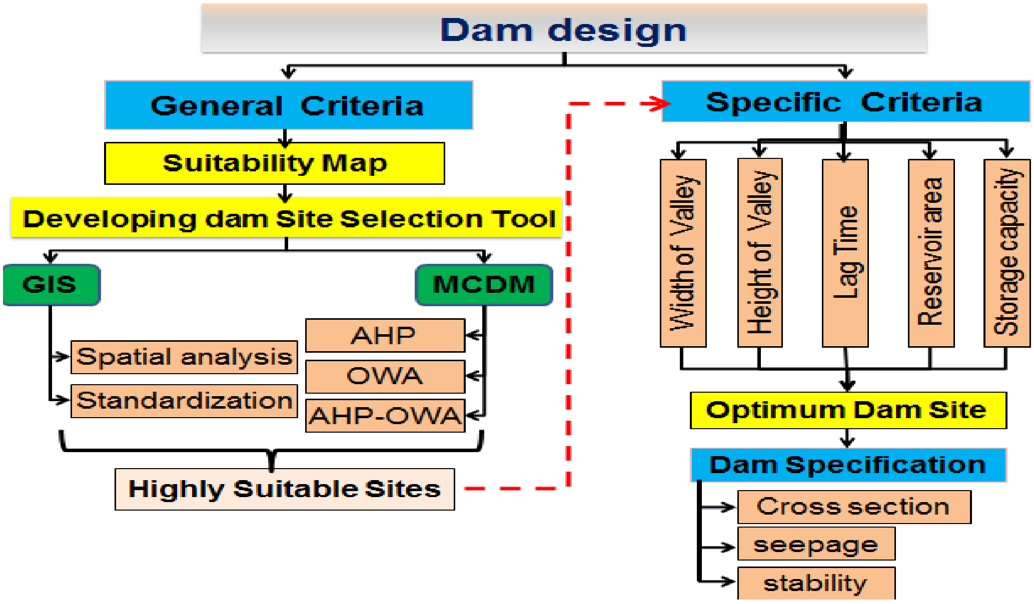

Fig.*(***1***):*-General Methodology for Dam Design

To implement the proposed GIS-based MCE approach for dam site selection, A tool was written using C# programming language in Visual Studio 2008 environmental as a toolbar within ArcGIS desktop. As shown in Figure (2) a Dam Site Selection Toolbar is comprised of three main menus (data standardization, and AHP, OWA, AHP/OWA methods)[1]

Fig.(**2**):-Dam Site selection using GIS-based MCE toolbar

2. Case study:

We applied the AHP-OWA Procedures based on geographic information systems (GIS) to fined dam locations along the El Kebir Shemaly River part which located in the Northeast of Latakia city, Syria [1] , Figure (3) .

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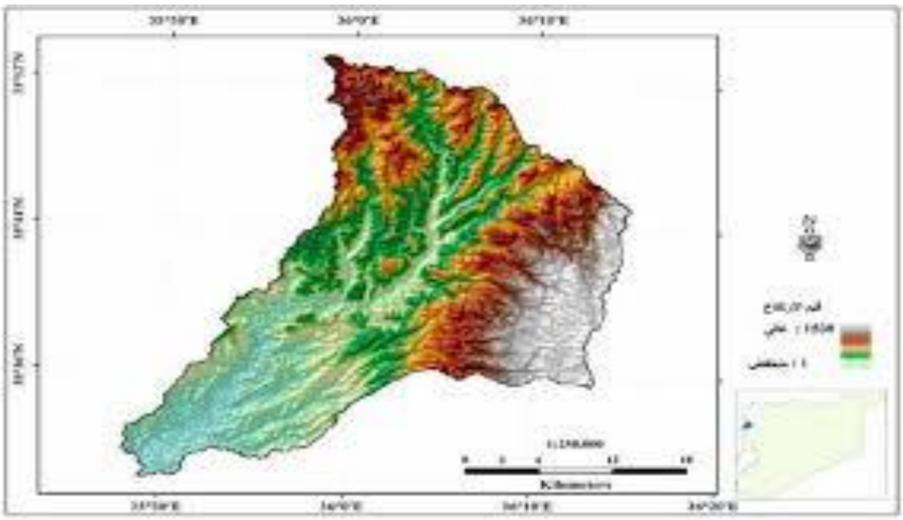

Fig.*(3)*:-Location of El Kebir Sheemaly basin

Eight criteria considered as factors affecting the optimum dam site in Kabeer basin for irrigation and supply demand were adopted in this study: the environmental criteria (slope, soil, geology, landuse), the hydrological criteria (rainfall, drainage network), the socio-economic criteria (distance from roads, distance from target area) factors [1].

The results of the scenarios were assigned a class between 1 and 5 depending on their suitability for siting a water reservoir. The higher the score is, the more suitable the area is for siting a water reservoir [1].

Finally we suggested four locations of dams in Kabeer Al Shemaly River as shown in Figure (4).

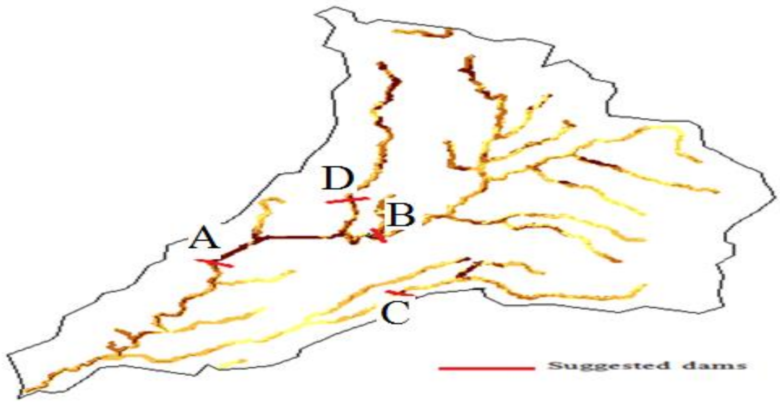

Fig.*(4)*:-suggested locations dams (AHP procedures)

After we determined the highly suitable sites in El Kebir Sheemaly basin , the Second stage is finding the optimum dam site from suitability map using specific criteria.

Addition of criteria of engineering, hydrology, and economic evaluations, to choose the optimum location such as storage capacity, construction cost, height of dam, length, reservoir area …etc. was done. Using AHP, we compare between them. The decision- makers have suggest four sites known as A, B, C, and D. The decision makers compared between the four sites using Pairwise comparison method[5]

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Table(1):-The synthesis of the results obtained has resulted

Alternative(A)	alternative(B)	alternative(C)	alternative(D)
0.606	0.141	0.145	0.121

This assessment allows to order the actions in the following way: Alternative A (0.606) proves to be the most suitable, followed by alternative C (0.145). Alternative B (0.141) is situated in the middle of the ordering, and alternative D (0.121) is placed at the end of the ordering. This result shows well the precision obtained from the proposed analysis as well as the strong significance of the values obtained.

finally the third stage of the methodology is design of the cross section of suggested dam.

We suggested to build dams on Kneceh branch. It is a tributary of the northern reaches of Kabeer Sheemaly River. It starts from Frolok forest and flows to meet with Qantarar branch then passes Ain Arab Valley, and then going through the Valley of Jouret Al Maeh to meet with Kabeer sheemaly River.Figure (5) shows the location of breach basin.

he new reservoirs are intended for the ponding of irrigation water and domestic water supply to the nearest village, and for regulator discharge of Kneseh branch and avoid floods.

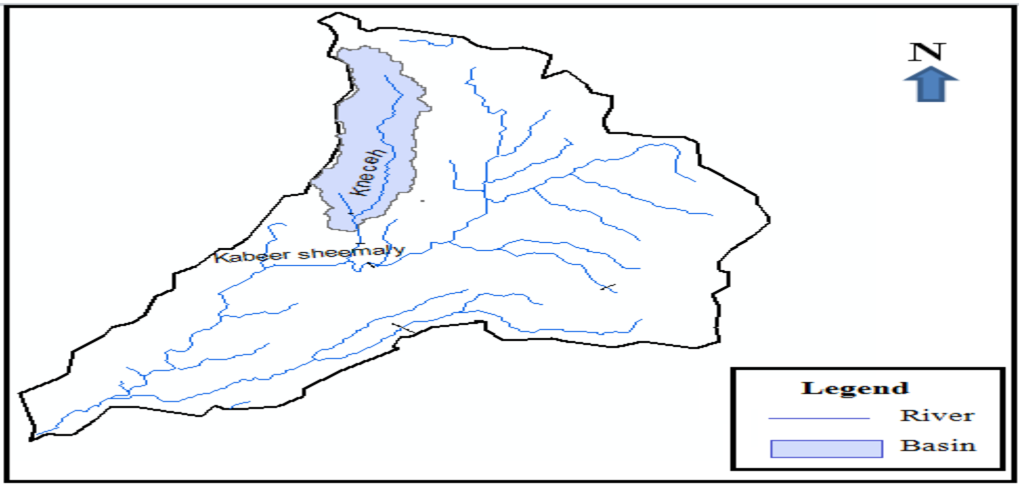

Fig.*(5):*-Kneceh Branch

As we had in the previous step the dam D is site in Kneceh Branch, Using the Batch Watershed Delineation function (Watershed Processing Menu) in ArcHydro 9. The results are given in Table (2):

Table (2):- Properties of dam reservoir

	Object ID	Shape_ Area (Km2)	storage Volume (106m3)	Flood elevation (m)
Dam **1**	84	0.37329	5.5	124

The final stage of design earth dam after selecting the sites is design the cross section of dam.

General slope dipping reaches 30o to 40o.There are practically no alluvial formations. Locally they are marine limestones, marls, clays, conglomerates, sandstones, and anti-Lebanon-Palmyrides continental quartz sands at the site. The soil at the site is of low permeability and small capability of holding the water.

Also we found at the site that the valley shape suggest to select Embankment dam with core . the description of the water reservoir and the dam parameters for the approved sites are presented in Table (3):

Table(2): -Dams description

Site parameters	Dam1
Reservoir volume (m3)	5498911.3
Reservoir area (m2)	3730000
Upstream slope ratio	3.5
DS stream slope ratio	2.5
Height of the dam (m)	44
Crest width (m)	8
Base Length of the dam (m)	280
Base elevation (m)	82
Normal water level (NWL)	123
Max water level (MWL)	124
Dead water level (DWL)	95

3. Seepage Study:

According to the materials located in the body of embankment dam, there is seepage through the dam's body which following a phreatic surface. Where the phreatic surface was considered an upper boundary .Dam is rest on an impervious layer. The water level at upstream is 41 m whereas the water level at downstream is 0m.

Seepage through the dam with shell of sand soil (k=1.e-005 m/sec) and core in two cases of soil type (clay or silt) is studied using SEEP/W software. Blanket of gravel (0.01 m/sec) The finite element mesh of the geometry in seep/w software is shown in Figure (7)

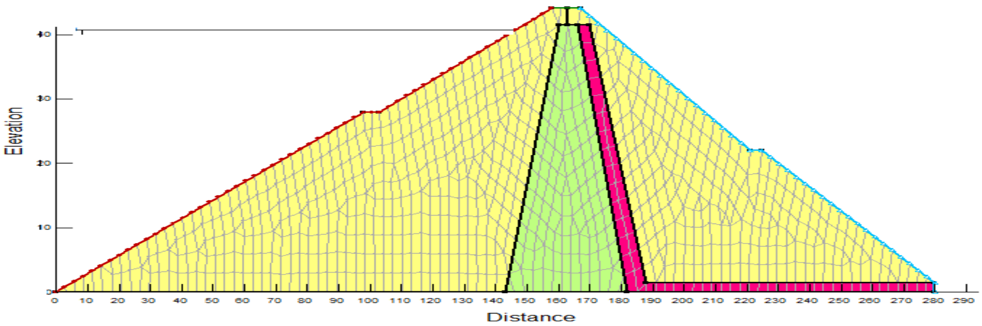

Fig.*(7):*-Finite Element Mesh of the Geometry in SEEP/W Software

CASE1 (clay core k =10-7 m/sec):

The seepage in dam with shell of sand soil and core with clay soil, by using the Seep/W software is calculated. Figure (8) shows the location of phreatic surface. The losses quantity at section (1) using constant model is q =0.00010641 (m3/sec)

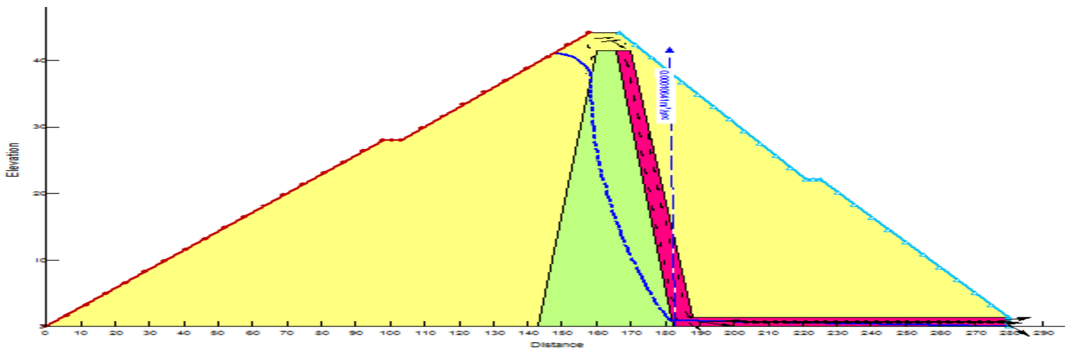

Fig.(**8**)*:*-Location of Phreatic Surface in cases 1

CASE2 (silt core k =10^-6 m/sec):

The seepage in dam with shell of sand soil and core with silt soil, by using the seep/w software is calculated. Figure (9) shows the location of phreatic surface. The losses quantity at section (1) using constant model is q =0.00015783 (m3/sec)

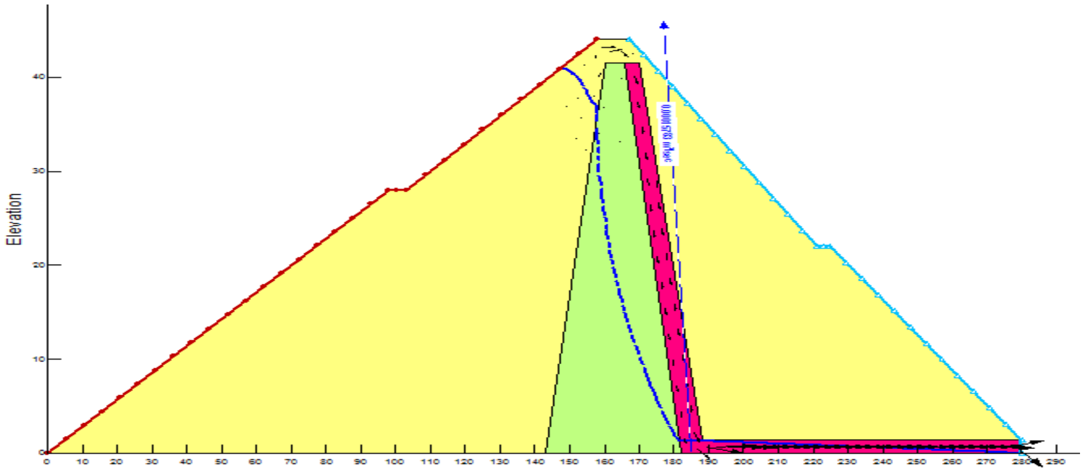

Fig.(9):-Location of Phreatic Surface in cases 2

4. Slope stability:

Analyzing the stability of earth structures is very important. After design the cross section the minimum factor of safety and located the critical slip surface are computed using SLOPE/W in GeoStudio.

We must take the seismic effect when design the cross section if available the data in the basin. using slices method the result that we get from SLOPE/W software is:

Upstream side factor of safety Figure (10).=2.73

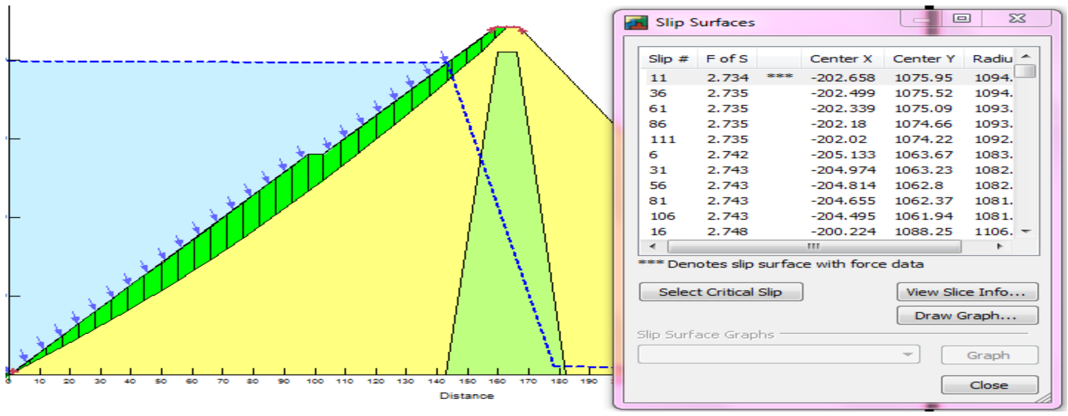

Fig.(10):-Upstream Side Factor

Downstream side factor of safety Figure (11)= 1.912

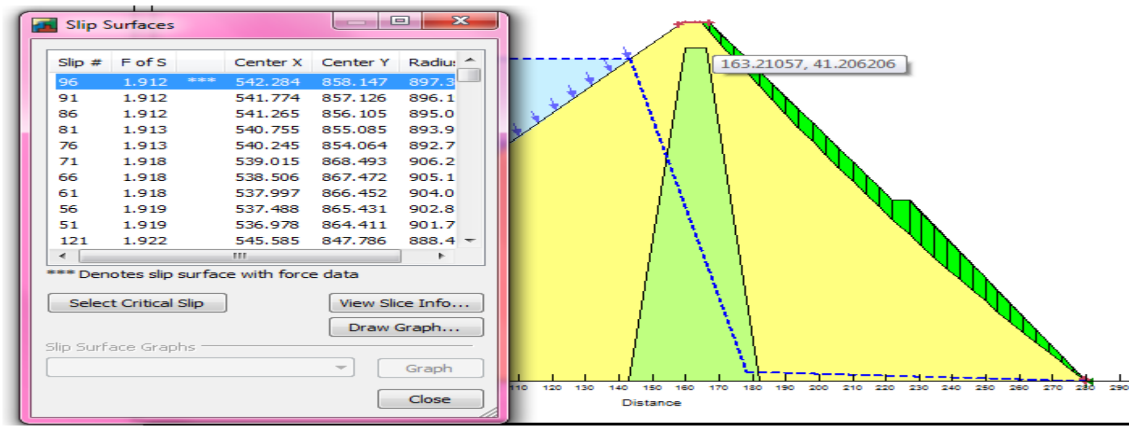

Fig.(11):-Down Stream Side Factor

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Comparing the upstream/Downstream side factor with Design factor, we found that the sides are stable

5. CONCLUSIONS

1. We found that GIS-MCDM in dam site selection would simplify the definition of decision strategies and facilitate an exploratory analysis in short time and less effort.
2. The newly developed tool classifies the proposed dam locations inside large area at the same time based on the degree of satisfaction of the selected criteria, while the traditional methods study single site per time.
3. We can use the tool to compare between some alternatives so getting some scenarios, according to spatial criteria.

REFERENCES

AlJubaely R,2016 "Application Of GIS AND Multicriteria Decision Making In Support Of Earth -Fill Dam Design" , Faculy of Engineering, GIZA, EGYPT , 2016 Cairo University,

Boldaje ,et.al. , 2011, "Site Selection of Eastablishment of Small Earth Dams in SemiArid and Arid Zones by Spatial Multi _Criteria Evaluation (SMCE) (Case Study YOOSEF-ABAD Watershed " : JOURNAL OF WATER SCIENCES AND ENGINEERING.p.p 31 To 40].

Johannes van and john,2011, ― GIS analysis for multicriteria reservoir site selection: NISP project,colorado : ESRI international user conference, San Diego Convention Center.].

Iranzadeh.,S Razifar., H,and Khalilpour., K ,2013 ,"Selection optimal type of dam using AHP method", Journal of Novel Applied Sciences, 2 (S) p.p 851-855, .].

AlJubaely R,2016 " Dam Site Selection Using GIS-Based AHP-OWA Approach Case study: El Kebir Shemaly River, Syria",Journal of al Azhar University,ISSN:1110-6409

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