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Geospatial Information to Enhance Sudan`s Agriculture Sector Investment

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Abstract— *In Sudan, the agriculture sector is constantly, seeking optimization to remain competitive and sustainable in the investment market. Geospatial data in the context of agriculture plays a pivotal role in every stage of the agriculture production life cycle, from planning and feasibility prospecting, through site selection for plantation to harvesting, marketing, and production optimization. Recent advancements in geospatial information technologies, such as Geographic Information Systems (GIS), positioning, aerial bone photogrammetric and Lidar, and remote sensing satellite imagery, have made it possible to collect, analyze, and visualize geospatial data in discoverable competitive ways. These technologies enable agriculture entities, in public and private sectors to make informed decisions based on accurate, real-time information, minimizing risks and maximizing benefits and production efficiency. Sudan has introduced the implementation of geographic information technology. It has made significant progress in developing and reforming government institutions to improve its geographic information productivity so that development programs and investment opportunities can achieve national goals in various investment sectors, according to the geographic databases of the Ministry of Agriculture and Forestry and its partners. This was meant to bridge the agriculture development gap between the states of Sudan. The paper also, emphasizes that implementing and integrating agricultural geospatial data can improve the productivity of the agriculture sector by providing valuable insights that benefit the decision-making, operations, and management processes.*

Keywords— *MIIC, SSA, AI, MoAF, UNGGIM, GGRF, IGIF, GNSS, SNBS.*

I. INTRODUCTION

The Ministry of Investment and International Corporation (MIIC). will activate Geospatial Information for Sudan's Sustainable Investment with the participation of its stakeholders for the preparation and implementation of the Sudan investment map, based on the directives and objectives of the government of Sudan and the Ministry of Investment and International Corporation. The Ministry of Agriculture and Forest (MoAF) has a strategic partnership with MIIC to develop and implement an Agricultural Geospatial Information system linked with Sudan's Investment map. The goal is to maintain the investment criteria and to align with the United Nations' sustainable development goals. The Sudan Survey Authority (SSA) has maintained the Sudan digital base map covering the entire country and developed data models and geospatial Information systems to be integrated with all stakeholder databases [1, 2]. The main stakeholders and partners of the Federal Ministry of Agriculture and Forest are the government and,private agricultural institutions, the Ministry of Livestock, the Ministry of Water Resources, the Ministry of Industry and Trade, the 'Ministry of Investment, the agricultural banks, the Employers Union, all the18 ministries of agriculture of Sudan states, as well as the agricultural departments of the various administrative localities.

This paper comes within the framework of activating the efforts of the Ministries of Agriculture and MIIC to develop agricultural investment services through the application of approved geospatial information technologies and applications in Sudan. This type of agricultural geospatial information is mainly carried out by the MoAF, through cooperation with its stakeholders and partners, which aims to raise the country's geospatial standing and to maintain the United Nations Global Geospatial Information Management (UNGGIM) Initiative [13]. The SSA will provide both, the MIC and MoAF with the Sudan National digital base map to be used as a base for all geospatial information provided by the two Ministries and their strategic partners from the public government and private sector organizations.

Today's geospatial systems in Sudan require accurate geodetic references and integrated geospatial information frameworks [12, 13]. These frameworks are essential for sharing, integrating, and exchanging geospatial data. They will help every institution in Sudan, including the MoAF, to expand their capabilities for enhancing, agricultural data collection and management. This will raise the level of support for geospatial data activities and provide solutions that enable the effective implementation of operations in the agriculture investment sector.

Geospatial/spatial data in agriculture is a data technique used to extract information from the data that belongs to a particular public, private, or agricultural scheme. Geospatial agricultural data contains information about the boundaries, location, area characteristics, topography, soil, hydrology, environments, population, policies, and funding. The basic topographic data and information can be extracted using geographic coordinates, satellite imagery data, and line and thematic maps. For example, by considering the context of the agricultural scheme boundaries or locations in the analysis, agricultural data allows for better investigation of the soil, water resources, socioeconomic and environmental impact, and decision-making in the areas related to urban planning, transportation, communication, public health, and production.

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In the coming years, Sudan's agriculture sector will be crucial for its economy.

Advancements in geospatial technologies such as positioning, Geographic Information Systems (GIS), aerial photogrammetric, Lidar, remote sensing satellite imagery, and artificial intelligence have improved the ways, geospatial data is collected, analyzed, and visualized. Thus, geospatial information is a valuable asset for optimizing agricultural processes, operations, and management to enhance profitability. By utilizing, agricultural data, the MoAF and its partners can make well-informed decisions about planting locations, necessary irrigation and plantation technologies, and efficient and sustainable agriculture operations. Geospatial data can be acquired from various sources, including satellite imagery, aerial photogrammetric, drone or Unmanned Aerial Vehicles (UAV) imagery, traditional ground surveys, mobile Lidar scanning, and GIS technology.

Geospatial data, with its accurate capturing of the Earth's features and spatial relationships, provides the information needed to optimize every stage of the agriculture process, from planning and plantation to production, which can be considered the foundation on which successful, sustainable agriculture operations are built. In addition to these operational challenges, environmental monitoring and crop classification are vital to minimize, the environmental impact and effectively adhere to increasingly stringent regulatory standards.

II. Sudan Agriculture Systems and Schemes

The traditional rain-fed sector is crucial in Sudan's food security, economic development, and poverty reduction [3]. It represents the largest share of the land area, with the majority, of the population engaged in agriculture. This sector contributes significantly to providing the country's food needs, as well as to exports and foreign currency earnings. Currently, the traditional rain-fed sector contributes, approximately 90% of gum Arabic and groundnut production, 95% of millet production, and 17% of sorghum production. Traditional, agriculture is extensively practiced in all sandy and clay areas. The emergence and development of the rain-fed sector relied on local cultures to meet the basic needs of the region's citizens .It represents the main contributor to the total area allocated to the production of the four most important food crops, sorghum, sesame, millet, and groundnuts .Likewise, both Gum Arabic and livestock are produced in the rain-fed sector [3,20]. The most important traditional rain-fed sector areas are located, in the states, of Greater Darfur, Greater Kordofan, Blue Nile, and White Nile, (Figure 1).

A. Rain-fed and irrigated agriculturalschemes and projects

Agricultural production in Sudan is practiced using different systems, namely irrigated agriculture and rain-fed agriculture which includes two sectors, semi-mechanized spread especially in Plains Clay Central, And agricultural Traditional spread in Different areas around Sudan such as western Sudan, and the flood irrigation system (Tokar and Al-Gash) and on the banks of various rivers, all of which are affected by rain. Arable land is estimated at 175 million acres of which only about 42-54 million acres are currently exploited in the following sectors [18, 19]: -

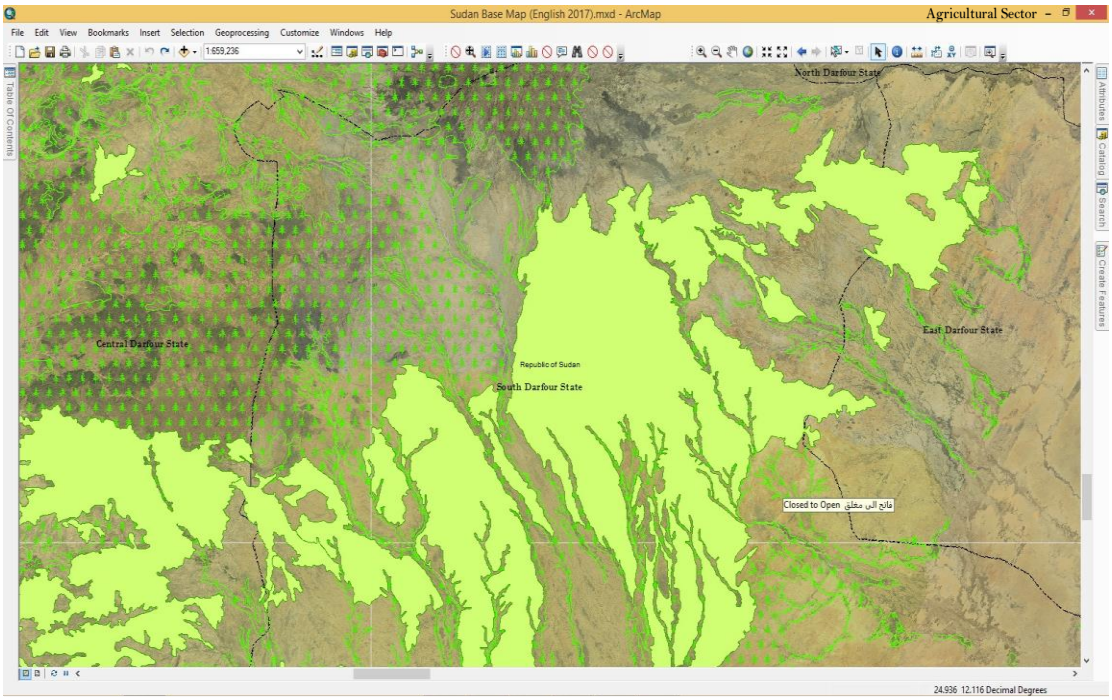

Figure 1: Sample of rain-fed in the agriculture sector

a) Rainfall sector: Cultivated areas vary depending on the amount of rain and the availability of inputs. Harvested areas, production, and productivity vary according to the quantity and distribution of rainfall and the availability of agricultural inputs (fuel), agricultural machinery financing and improved seeds. The sector is divided into: -

(i) Semi-mechanized rain sector: It represents about 32% of the total cultivated area spread ,in Gedaref, South Kordofan Blue Nile, White Nile, and Kassala States.
(ii) Traditional rain sector: It represents about 58% of the total cultivated area in Sudan It is spread throughout most parts ,of Sudan and is concentrated in the states of Kordofan Darfur, Sennar, White Nile, and Blue Nile. It is characterized by small holdings with an abundance of livestock.

b) *Irrigated sector*: Representing about 10% of the cultivated area in Sudan, irrigated agriculture is practiced in flat plains with rare highlands, on the banks of the Nile River and its tributaries, valleys, and creeks, in a climate ranging from desert to rich savannah.

The main irrigated agriculture schemes in Sudan are: -

(i) National agricultural Schemes: - Al Jazeera, New Halfa, Al Rahad, and Al Suki.
(ii) Devolution projects: in the states of Sennar, White Nile, River Nile, and the Northern states
(iii) Flood irrigation schemes: - Tokar Delta, Al-Gash, and Khor Abu Habal
(vi) Private sector projects: irrigation with pumps from the Nile and traditional irrigated agriculture on islands, cliffs, creeks and wells.
(v) Sugar projects: Sudanese Sugar Company, Kenana Sugar and White Nile. Average cultivated crop areas in irrigated and rain-fed sectors are shown in Table 1. Starting from 2003 to date despite the war conditions that the country is experiencing, the Federal Ministry of Agriculture and Forest has continuously supported the Sudan states with improved seeds to be provided for low income farmers. This, program aims to raise crop productivity and spread the culture of using improved seeds among farmers to achieve food security. On the other hand, the extension department spread across the states 'conduct farmers training to educate farmers about the importance of applying technologies and their role in increasing production. This work is strengthened by establishing experimental farms among farmers' fields to motivate them to use these technologies. The Ministry of Agriculture and Forest established the Integrated Solutions Department, which played a major role in supporting farmers technologies and providing all modern agricultural.

TABLE 1. A sample of average areas of the cultivated crops in the irrigated and rain-fed sectors

The crop	Irrigated sector (1000 acre)	Rain sector (1000 acre)	Total crop area (1000 acre)
Sorghum	965	21,088	22,053
Millet	30	7,200	7,230
Wheat	800	0	800
Sesame	10	5,490	5,500
Groundnuts	330	5,120	5,450
Sunflower	240	450	690
Cotton	560	300	860
Vegetables and others*	835	1,613	2,448
Total area	**3,770**	**41,261**	**45,031**

- Others include: hibiscus - watermelon seeds - guarrice – vegetables -

The Federal Ministry of Agriculture represented by the general administration of plant protection distributes quotas of pesticides to the various states in the country. It also conducted collaborative work with the neighboring countries to control pests across the continent.

Agricultural soils in Sudan vary depending on the location of agriculture schemes. The main soil types include sandy dunes, clay, and Celtic soils, as well as red and mountainous soil. 80% of the crops are grown in rain-fed sector areas, and these include crops such as sorghum, millet, groundnuts, sesame, cotton, sunflower, watermelon, hibiscus, gum Arabic, guar, maize, cowpeas, legumes, fodder, rain wheat, fruits, and vegetables. These crops make a significant contribution to the national agricultural product export.

The main agricultural infrastructure comprises:

a. Transportation infrastructure, which includes roads and railways. These are essential agricultural infrastructure services that contribute to the development of the agricultural process and are the backbone of agricultural renaissance programs.
b. Water resources infrastructure, including water supply, treatment, and storage systems, water resource management, water harvesting, flood prevention, and hydroelectric energy.
c. Storage infrastructure, including silos for grains and coolers for storing fruits and vegetables.

B. Challenges of Agricultural Production in Sudan

a. Lack of fixed agricultural policies and national strategic plans
b. Low productivity per acre
c. Lack of adequate financing and insurance for the various stages of agriculture
d. No local agricultural-manufacturing inputs ,fertilizer) (.pesticides, etc
e. Weakness or absence of the value-added.chain for crops
f. Weak agricultural infrastructure (roadssilos agricultural extension centersetc ,).

2.2 Agricultural financing

Agricultural financing is intended for, the provision, of necessary funds to carry out the agriculture production processes, such as agriculture production and reproduction, and what follows from the activities of storage, transportation, sales, and marketing.

There are many mechanisms through which funding can be directed to the agriculture sector [21]. Agricultural financing can be done from farmers' self-financing or the government's local and external funding sources (Figure 2).

The Agricultural Bank provides financing to farmers and agricultural projects in the country. The financing is seasonal and it returns at the end of the season. The bank's primary objective is to offer funding for various types of agricultural activities through the applicable banking systems within the framework of the general financial policy in Sudan. Additionally, the bank provides most of the agricultural supplies needed by farmers, including loans for purchasing pesticides and improving seed, as well as the necessary agricultural technology. In its financing policy, the Agricultural Bank links financing to the use of technical packages, which

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has led to increased productivity and the spread of technology adoption among farmers.

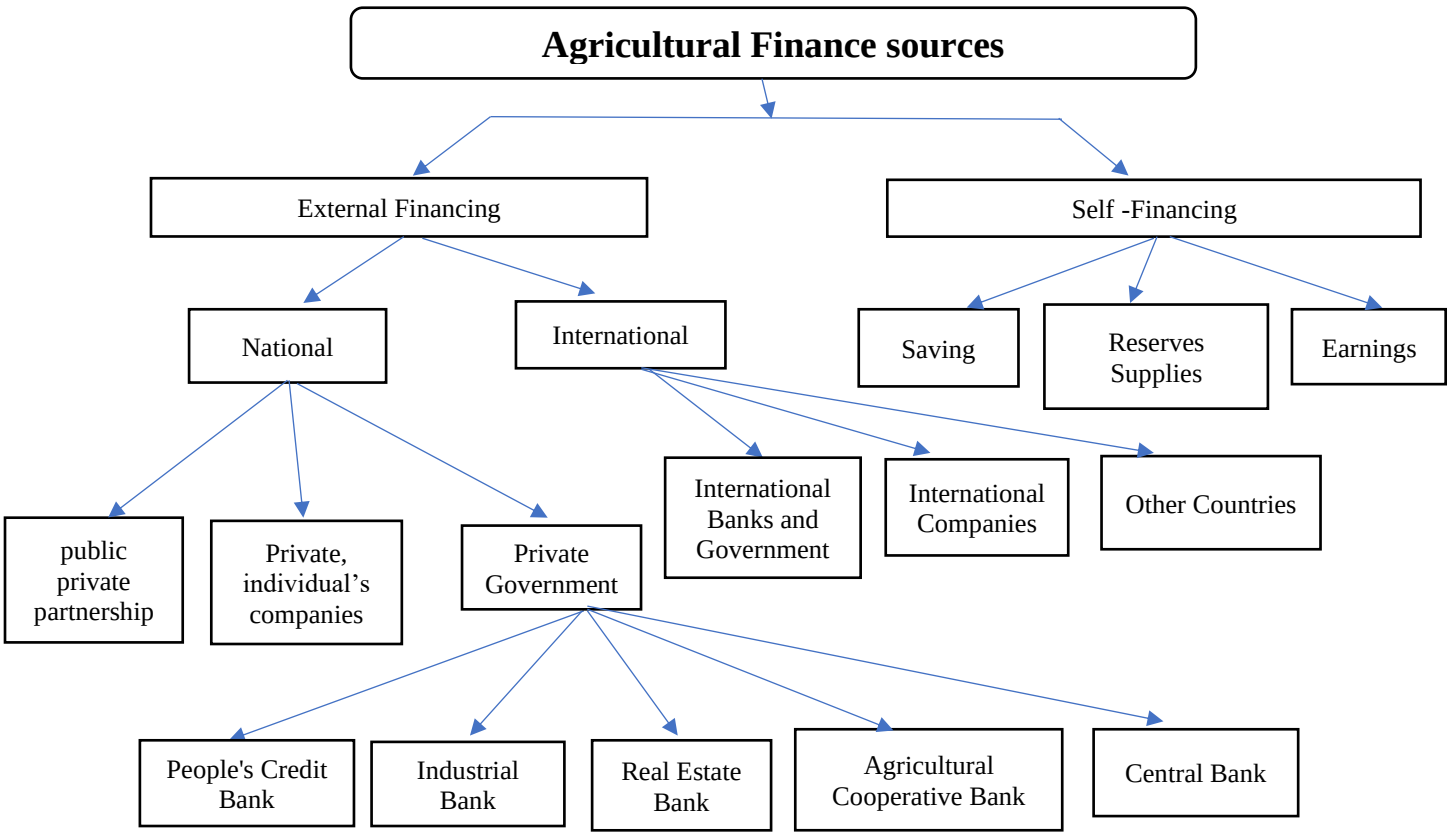

Figure 2: shows Sudan's agricultural financing in various sources

III. Geospatial Data and Optimization of Agriculture Processes

The most important types of agriculture surveying are as follows [3, 10]:

(a) Geodetic surveying: Concerned with the essential agriculture areas boundaries, planning, and operations, by providing accurate information about the reference systems, coordinates of control points, and other necessary points on the horizontal and vertical levels, baselines, and determining heights and directions. It is also concerned with establishing geodetic networks and establishing precise reference points to which all other agriculture works are linked. Agriculture survey work at all stages requires geodetic work and measurements, especially those requiring high positioning and height accuracy.

(b) Plane surveying is commonly used in various stages of agricultural surveying. It connects planned agricultural area measurements to geodetic networks and control points. This type of surveying assumes the ground surface to be flat.

(c) Photogrammetric: Aerial photography, UAVs, and airborne Lidar are considered as a means of obtaining geospatial information about natural and agricultural target areas, which are carried out through measurements from aerial photographs using indirect methods. Photogrammetry is concerned with obtaining information about natural and man-made mapping by making measurements from aerial photographs. Aerial photogrammetry requires processes of, planning, collecting data from the photography site, carrying out aerial photography measurements, and image processing. Ultimately, it is also used for producing topographical and thematic maps and orthophoto maps.

(d) Remote Sensing: Remote sensing is a means of obtaining information about natural and topographic features from image measurements and preparing maps from satellite images. Remote sensing is considered one of the most important sciences that has enabled the study of the Earth's natural resources, including agriculture, vegetation, forests, and hydrology in a broad and precise manner. Remote sensing can also be used in continuous, periodic monitoring of agricultural areas and observation of the Earth's environment.

Geospatial agriculture data plays a crucial role in agricultural operations as it encompasses a variety of sources and types. It accurately captures ground features and spatial relationships, providing essential information for optimizing every stage of the agricultural process, from planning and plantation to irrigation and production. Therefore, geospatial information is fundamental for the success and sustainability of agricultural operations. Sources of geospatial agriculture data include satellite images, aerial photography, UAV drones, ground surveys, and GIS analysis and visualization. Additionally, GIS

can store data from various sources and be used to create detailed maps and models of agricultural areas.

Geospatial data types can be divided into multiple categories based on their properties and representation. Different types of data are used in agriculture represented in the form of point data, linear, polygon, raster, and image data, which can be defined as follows: -

(i) Point data: Point data represents a single location or a group of locations on a map or geospatial layer. Each point is identified by geographic coordinates (latitude and longitude) or UTM projection coordinates in the form of, easting's E and northing's, N locations in geographic space. Point data is commonly used to represent geographic features such as land, cities, landmarks, or specific points of interest in small-scale mapping.

(ii) Line data: Line data contains a series of points in the form, of lines or curves. It is used, to represent linear entities, such as rivers, irrigation canals, pipelines, and roads on a map or geospatial layer.

(iii) Polygon Data: Polygon data consists of regions in space that represent closed shapes, a region on the map, or an agricultural layer. Each polygon is defined by a set of vertices that connect to form a closed boundary. Polygon data are commonly used to represent administrative boundaries, concession areas, land use, pass zones, plots of land, lakes or forests, and reservoirs.

(iv) Raster Data: Raster data refers to space as a grid of pixels, where each cell in the grid represents some feature. It is used to represent phenomena such as remote sensing images or image data, as the name suggests, consists of spatial data in the form of images. It is often used for object detection, capturing visual information about the Earth, land cover classification, etc.

IV. Ministry of Investment & International Cooperation and Sudan Agriculture Sector

The Ministry of Investment in Sudan has outlined its commitment to leveraging the investment map as a framework (Figure 4) to boost investment in the country and develop executive regulations for technical services. This includes aligning with policies approved by the Government of Sudan and stakeholders, such as the Ministry of Agriculture and Forest, to enhance agriculture investment operations. The Sudanese Survey Authority (SSA) plays a crucial role in the partnership between the Ministries of Investment and the Ministry of Agriculture and Forest to integrate cadastral data and geospatial information for activities like Agriculture (Figure 1) and investment into a national map framework. As a national leader in geospatial data and geographic information technology, the SSA is responsible for the National Base map and shaping the country's frame of reference. They are working on various initiatives to advance the geospatial landscape in Sudan and support the nation's digital development. Additionally, the SSA acts as the central regulatory body for implementing Geospatial Information Management, focusing on sustainable national development. They advocate for unified global reference frameworks and have established a system for federal and state governments to benefit from the Sudan National Base Map System (SNBS). By collaborating with organizations and entities across Sudan, the SSA aims to improve access, sharing, and integration of geospatial information for informed decision-making processes. These efforts align with the United Nations Global Geospatial Information Management (GGIM) initiative, which seeks to improve global access to geospatial data for sustainable development. The initiative focuses on enhancing the use, accessibility, and quality of geospatial data worldwide by promoting best practices, standards, and policies. The United Nations Integrated Geospatial Information Framework (UN-IGIF) and the United Nations Global Geodetic Reference Framework (UN-GGRF) are central components of this initiative, aiming to bridge the geospatial digital divide and ensure global consistency and accuracy in measurements related to Earth's shape and position.

To find investment opportunities in the government sectors, it's important to identify areas with strong demand, potential for import substitution, and significant competitive advantages. This is especially true for expanding exports. The Ministry of Investment is considering the Investment Map approach developed by Harvard University and the Massachusetts Institute of Technology [16, 21]. This approach involves analyzing the connections between manufactured and exported goods and exploring the possibility of shifting towards premium goods manufactured with high levels of local production, this requires a clear and precise scientific methodology tailored to the nature and objectives of the required, investment map, as well as its geographical and sectoral scope.

It's important to fully understand the investment process by examining its components and the surrounding environment. To successfully convert investment ideas into viable projects, it's crucial to have an attractive and cost-effective environment in place. This includes favorable working conditions, essential investment foundations like financing, infrastructure, logistical services, and easy access to production inputs. Furthermore, there should be, both local and external demand to ensure profitability for the projects outlined in the investment plan, analyzing value chains and supply chains to develop integrated industrial clusters forms the basis for examining potential sectors.

A. Sudan Agricultural-Related Resources

Sudan is distinguished by its vast economic resources, which amount to eighteen million acres of arable land, more than all the Arab countries combined.

These lands contain one-sixth of the world's cracked clay lands with fertile agricultural land exploited in its best conditions, reaching 58 million acres in addition to 115 million acres of pastures and 56 million acres of forests, in addition to its multiple climates that enable it to cultivate three seasons (all-year round cultivation) in addition to the availability of water above and below the ground is fed by sustainable abundant rainfall rates and its share of the Nile waters, estimated at 18.5 billion cubic meters, of which 12.2 billion cubic meters are exported according to the Nile water Agreement of 1959. There

are summer rains from May to October that cover all parts of Sudan and winter rain in the Red Sea State and Jebel Marra.

Sudan exports 80% of the world's gum Arabic and 40% of groundnuts and is ranked sixth in sesame production and export. As for livestock, Sudan has 108 million sheep, 2 million horses, and 4 million camels.

Despite Sudan's huge resources, its economy has fluctuated between recovery and recession as a result of several intertwined and interconnected internal factors related to economic financial, and monetary policies, weak political, social, security, and cultural stability, in addition to administrative weakness.

The investment map seeks to address the imbalance, support the positives, and avoid the negatives.

B. Methodology for preparing investment maps:

The process of preparing investment maps is in several sequential and interconnected stages. Overall, the methodology may be in line with the methodology developed by the Arab Planning Institute for building investment maps based on the fact that promising and new investment opportunities lie primarily in identifying the missing links in industrial clusters, value chains, and productive supply chains [21]. Given the nature of developing economies, which suffer from identifying these missing links and activities in the production chains of goods and services and working to direct investment on them.

The trend towards completing these cycles or activities in it represents a necessity and a basic requirement for planning aimed at enhancing competitiveness, due to its role in strengthening backward and forward connections, which increases collective productivity. Investment opportunities can also possibly to identify investment opportunities in new sectors that are linked to strong demand, import substitution, and the presence of significant competitive advantages, especially in the field of enhancing exports, by relying on the production and foreign trade matrix and the commodity space methodology, that has been developed by Harvard University and the Massachusetts Institute of Technology [16], which looks closely at the distances between manufactured and exported goods and considers the possibility of moving towards the rich region in the goods space, especially premium goods that are manufactured with the highest levels of local production towards emerging sectors and goods and redirecting production towards emerging sectors and commodities and withdrawing from the production of obsolete commodities. This process is carried out according to a clear and precise scientific methodology that depends on the nature and objectives of the required investment map and its geographical and sectoral scope. The process of preparing investment maps requires many components and primary and secondary data, complete and partial, and also requires the cooperation of all relevant governmental and non-governmental agencies.

The process of preparing investment maps starts with studying the economic and social reality in all its dimensions and indicators and identifying the strengths, weaknesses, and most important development challenges, based on a deep analysis of reality and the opinions of stakeholders from the public and private sectors. After completing the study of the economic and social reality and identifying the main leading and promising productive sectors, a clear picture is formed about the (natural, financial and human) economic capabilities and components, through which the competitive advantage, or those related to the markets and the prevailing consumption and productivity patterns, are determined. In order to reach a complete perception of the extent of ease of doing business activities, the investment environment and investment components are studied, based on the fact that investing available resources and transforming investment ideas and opportunities into projects capable of continuing will not be easy unless it will be an attractive, easy and inexpensive. Carrying out work of acceptable limits in addition to the availability of basic investment foundations such as financing, infrastructure, logistical services, in addition to easy access to production inputs and the availability of local and external demand to ensure profitability for the projects determined by the investment map and analysis of the leading and promising sectors based on the idea of analyzing value chains and supply chains and explaining their different paths and building … integrated industrial clusters.

V. SUDAN NATIONAL BASE AND AGRICULTURE AND INVESTMENT MAPS

The Sudan Survey Authority (SSA) offers effective solutions for collecting, editing, storing, and delivering geospatial data and information, implementing an improved information management system will significantly enhance support for SSA activities and the Sudan geospatial community. The Sudan National Base Map System (SNBS) (Figure 3) will ensure the delivery of the geospatial information management system at an acceptable level of confidentiality, availability, and performance. This will contribute to the effective management of geospatial information by maintaining acceptable levels of quality control procedures, confidentiality, secure service, and performance [1, 2, 5].

The investment map (Figure 4) is a document that outlines potential investment opportunities and serves as a comprehensive guide, providing investors with the necessary geographical, legislative, and procedural information to make informed investment decisions. It covers investment opportunities at both federal and state levels in Sudan and is an essential tool for highlighting specific projects. To create an effective investment map, collaboration between the Ministry of Investment and strategic partners such as the Ministry of Agriculture and Forest and the Ministry of Mining is essential. Geospatial information development involves the collection, organization, and management of geospatial data and a clear process has been identified to determine its geographical scope, framework, objectives, and strategic plans.

The methodology for preparing the Sudan investment maps used in Sudan is based on several sequential and interconnected stages. It relies primarily on identifying the missing links in industrial clusters, value chains, and productive supply chains within the developing economies of Sudan. These missing links and activities directly impact investment and require comprehensive analysis [16].

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Preparing investment maps involves gathering primary and secondary data, complete and partial, and requires cooperation from all relevant governmental and non-governmental agencies. The process begins with studying the economic and social reality in all its dimensions, identifying strengths, weaknesses, and development challenges. This is based on a deep analysis of reality and input from stakeholders in the public and private sectors. After studying the economic and social reality and identifying the leading and promising productive sectors in Sudan, a clear picture can be formed about the natural, financial, and human economic capabilities and components. This helps determine competitive advantages, market-related factors, and prevailing consumption and productivity patterns.

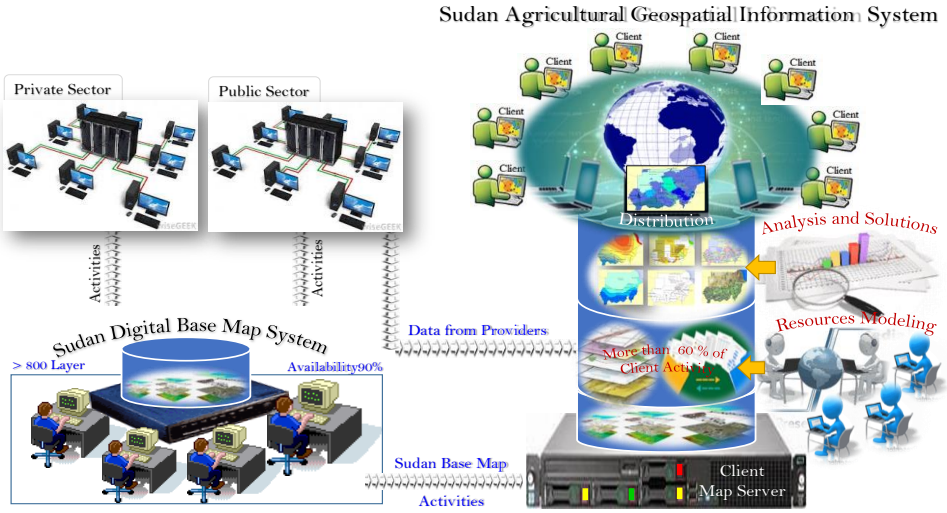

Figure 3: Base map interactions between the Sudan Survey Authority and the Clients

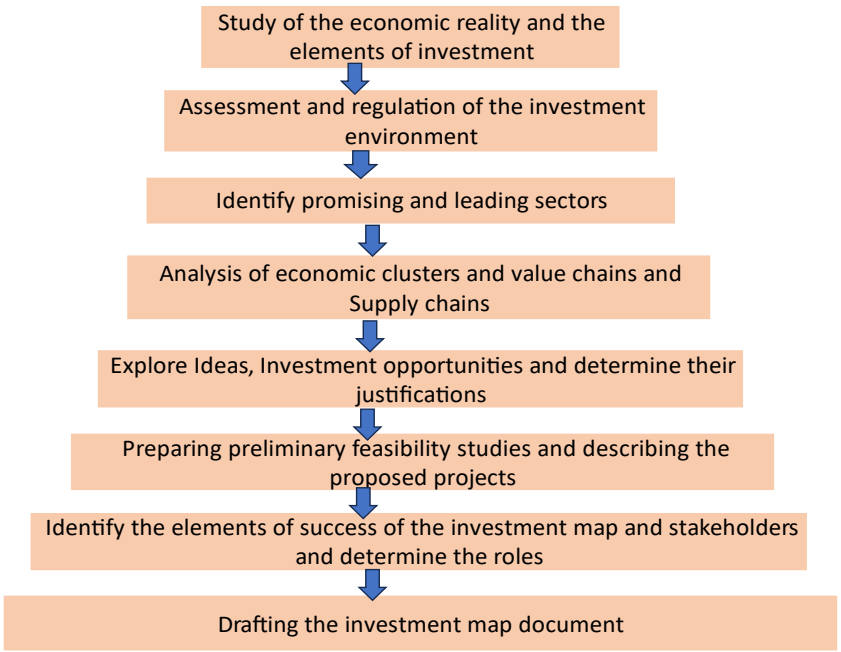

Figure 4: Stages of preparing investment opportunity maps [21]

VI. Geospatial Information and Agricultural Database

The Sudan Survey Authority provides crucial geospatial data and information that is essential for the sustainability of investment, mapping, and agriculture databases in Sudan. SSA data serves as the reference system for geospatial information. To develop a sustainable agricultural geospatial system, the authors call for a cooperation and partnership agreement to be reached between the Ministry of Investment, the Ministry of

Agriculture and Forest, and the Sudan Survey Authority to enhance the role of geospatial information systems in supporting investment sustainability in Sudan. The goal is to build a national framework for geospatial information, collect and process agriculture and investment data, create integrated databases, and establish mechanisms to update the geospatial data and information for relevant ministries and their partners in the public and private sectors.

TABLE 2: Shows a sample list of integrated agriculture geospatial data

Source	Common geospatial data layers and attributes	Responsible party
Sudan basic map data	• base map system, • International and national administrative borders; • Geodetic reference systems, control networks, and local and global geodetic models. • Terrain, DTM, Contours, • Raster images and aerial photography. • Water sources, rivers, drainage patterns, hydraulic structures, hydraulic structures. • Natural and artificial monuments, settlements, transport highways, railways, and tracks. • Land use, land cover, agriculture, vegetation, forests, • Telecommunications coverage, etc.	Sudanese Survey Authority
Spatial data for the states and the country	• Land surveying, property planning and maps, • Land use, cities, farms, settlements, • Population, education, and health facilities • facilities services,	Federal and state governments and partners
Agricultures Geospatial data	• Agriculture concession areas • Irrigation water information, water sources • Geological layers, faults, geological rocks, soil • Annual rain Rainfall data • Hydrogeology and groundwater information	Ministry of Agriculture and Forest

The current challenge faced by the creation of agriculture and investment databases, is the integration of datasets from multiple sources, each with different formats, semantics, resolutions, and coordinate systems. Agricultural data aims to extract previously unknown, useful information, patterns, and trends from the Ministry of Agriculture and Forest data and all its stakeholder entities. This involves various disciplines such as irrigation, rainfall, water sources, soil, agricultural engineering, geological and hydrogeological information, artificial intelligence, and machine learning for monitoring agriculture processes and crop classification.

This research focuses on activating geospatial information in the agriculture sector by integrating Sudan's base and investment maps with the current and future geospatial agricultural data and by-products of their transactional updates. The geospatial data needed for creating the farm information system is outlined in Table 2.

Geospatial data and information are used in agriculture to process relevant agriculture analysis. The featured category contains information about the items listed in Table 2, represented in the form of polygons indicating agricultural lands or cultivated areas. These polygons represent permitted spaces for agriculture schemes and companies, either as the area extent or surface projection of areas where undiscovered agriculture resources may exist. The dataset is created by the Ministry of Agriculture, in cooperation with its partners and stakeholders and companies. Extraction technologies used for agriculture geospatial data can utilize also artificial intelligence and machine learning techniques.

Analyzing geospatial agriculture data enables decision-makers to make more effective and constructive decisions. Specific techniques and methods for agriculture spatial data may include:

(a) Data collection techniques: This refers to the technology used to gather and organize data points based on their similarities, and is commonly used in agriculture to group similar geographical areas based on their characteristics.

(b) Classification techniques: This involves categorizing data points based on their attributes, and is used in agriculture data to classify geographic areas based on factors such as land use and soil type.

(c) Association rule agriculture: This technique is used to discover relationships between variables in a dataset. It can be applied in agriculture spatial data to identify correlations between different geographical variables, such as land use and environmental factors.

(d) Spatial regression: This technique models the relationship between a dependent variable and one or more independent variables, considering the spatial autocorrelation of the data. It is used in agriculture geospatial data to model the relationships between different geographical variables.

(e) Decision tree: A type of machine learning algorithm that is used to classify geographic areas based on their attributes. It can be applied in agriculture to determine the most important factors affecting land use, agriculture classifications, environmental factors, and other geographical variables.

(g) Machine learning is a subset of artificial intelligence that involves using algorithms to learn from data and make predictions or decisions. In agriculture classifications and analysis, there are various types of machine-learning techniques, such as: -

(i) Supervised Learning: The goal of supervised learning is to learn a function (say Y) that can predict the target variable accurately for new, unlabeled data. It is a type of machine learning algorithm that involves training a model on a labeled dataset with a known outcome or target variable for each data point. Examples of supervised learning algorithms include linear regression, logistic regression, decision trees, random forests, and support vector machines (SVMs).

(ii) Unsupervised Learning: Unsupervised learning seeks to discover patterns and structures in data. It is a type of machine-learning algorithm that involves training a model

on an unlabeled dataset without a specific target. Examples of unsupervised learning algorithms include principal component analysis (PCA) and anomaly detection.

(iii) Reinforcement Learning: In robotics, gaming AI, and control systems, reinforcement learning is frequently used. It is a type of machine learning algorithm where an agent learns to make decisions in an environment through trial and error. The agent is rewarded or punished for each action it takes, to increase the total reward over time.

(a) Interpretation and evaluation: The results of machine learning analysis must be interpreted and visualized before they can be communicated to stakeholders. Interpretation entails identifying the most important data features and patterns, while visualization entails the use of techniques such as crop classification maps, scatter plots, and interactive maps.

VII. Geospatial Information System for Agriculture

Geospatial Information Systems (GIS) for agriculture help describe objects, events, or features in places designated for agriculture processes, which are located on the surface of the Earth. Geospatial data combines location information (coordinates) and attribute information (characteristics of the object, event, or phenomena) along with temporal information (time or lifetime in which the location and attributes exist).

Geospatial data can be collected, shared, and analyzed. Given the volume of geospatial data, its organizations routinely require, many agriculture stakeholders have to look to geospatial services for data exchange, sharing, and integration. Data quality must always be maintained, regardless of the source of the geospatial data, as poor data leads to models of little or limited use. Aggregated or shared geospatial data should be analyzed and used to create data visualizations, including maps, graphs, and statistics, to display historical changes and current transformations.

The geospatial Investment map relates specifically to the physical mapping of agriculture data within a visual representation overlaid with other layers showing potential areas of agriculture activities, and helping with the analysis, administration, and modeling of agriculture data. Using geospatial data for agriculture provides many benefits to the agriculture sector enterprises, including:

- Better understanding of customers' or investors' preferences, behaviors, and associated characteristics, enabling the development of planning, production, targeted markets, and improved customer and client engagement.
- Improved operations through the identification of patterns and trends in the agriculture sector, leading to more efficient routing, reduced costs, and improved resource allocation.
- Making data-driven decisions based on geographic context, allowing for risk mitigation, identifying opportunities, and planning for future growth. This requires institutions to promote collaboration between agricultural databases and other geospatial databases to leverage the required information and ensure an acceptable approach for implementing agriculture activities.

VIII. Conclusion

Sudan has introduced the implementation of geographic information technology, and has made significant progress in the development and reform of government institutions to improve its geographic information products to be linked to the investment map of all government sectors. Development plans and investment opportunities have been focused on achieving national wise goals in various investment sectors through, the application of performance indicators, follow-up, and adjustments based on changing priorities.

The purpose of this paper is to present a way forward and provide data and spatial information to create a Sudan investment plan for inclusion in the databases of the agricultural sector, including agriculture companies of various sizes, and to bridge the development gap between the states of Sudan. The paper also, emphasizes that implementing and integrating geospatial data can improve the agriculture industry by providing valuable insights that benefit the decision-making process throughout the agriculture lifecycle activities.

Fundamentally, geospatial information can improve efficiency, safety, and quality of information as integrated with modern technologies like artificial intelligence and machine learning. These, are increasingly being used in the agriculture industry, leading to a promotable future in which agriculture operations and investment are further improved.

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