An investigation of ancient settlements in Sub-Sahara Africa a case of the ruins of Great Zimbabwe, using Artificial Intelligence with GIS to understand the pattern of the settlement and establish the morphology of the missing parts of the ruins.

By Kezala Jere

PhD IN ASIAN, AFRICAN AND MEDITERRANEAN STUDIES.

Table of Contents

1.0 Scientific-disciplinary sector to which the project refers

This a proposal that is based on the study of an ancient civilization called great Zimbabwe (an archeological site situated in Zimbabwe-Sub-Sahara Africa)(World Bank, n.d.). The proposal is aimed at conducting an investigation of Great Zimbabwe on an architectural planning perspective (building typology and morphology) intertwined with an archaeological approach, using the tool of Artificial Intelligence with Geographical Information Systems (GIS). Arguably, though it is debatable with some scholars on the authenticity of architectural planning being a scientific discipline, this investigation is intended to prove otherwise: Firstly, because this research proposes to add to the body of knowledge in that it is a study based on facts gotten through observation and the performing of experiments[1]. In this regard the building typology and morphology analysis is a rigorous and meticulous method of collecting data as a scientific method. The scientific archeological approach to be taken is to analyze the archeological site itself by mapping it using drone technology or any other related scientific method related to using Unmanned Aerial Vehicles (UAVs) that would be used to analyze the logic behind the settlement pattern of Great Zimbabwe. Secondly, the use of Artificial Intelligence (AI) which has now finally come firmly in the academic circles to be accepted and be considered a scientific method, would be used to drive the two intertwined disciplines of architecture and archeology in the investigation of Great Zimbabwe. Furthermore, in this proposal AI is concerned with the thought processes and reasoning used to understand a space like Great Zimbabwe, in this case, a human-centered approach[2] would be taken as an empirical science, involving observations and hypotheses about human behavior (Russell & Norvig, 2010) in understanding the settlements' pattern. Therefore, this proposal calls for hypotheses that will need to be subjected to rigorous empirical experiments, and the results to be analyzed statistically for their importance. Finally, part of the pattern analysis of Great Zimbabwe will be based on a spatial aspect using a GIS platform.

---

[1] Experiments of testing and trying different analyses carried out using computer software and statistical analysis.

[2] This human centred approach is the goal to understand the behaviour of the people in the use of the space (great Zimbabwe) being investigated to understand why and how it was used as a lesson for planning human settlements. That is the essence of understanding the pattern.
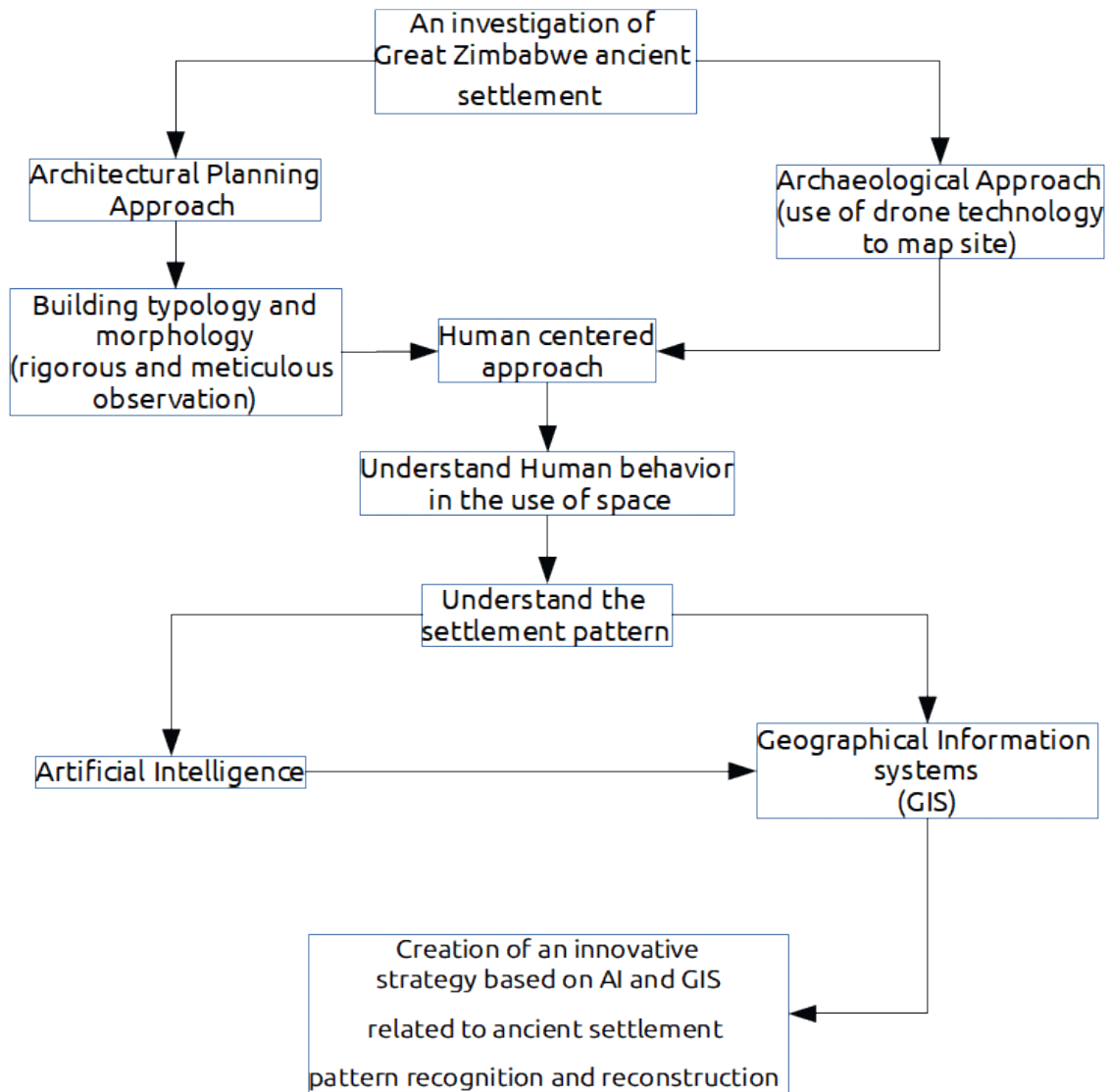
Figure 1.
The architecture and archeology approach combine with artificial intelligence.
Source: Author

2.0 Project abstract

The investigation of an ancient settlements is critical to understanding the culture or the way of life of the people living within that particular settlement, the way of life in this case gives us a hint of knowing the logic behind the spatial layout of the settlement. This proposal looks at the case of ruins of Great Zimbabwe as an ancient settlement, particularly looking at how the settlement was planned. Therefore, the justification thereof of this proposal is that little research has been done on analyzing an ancient site both on the architectural spatial approach and archeological approach.

This investigation is therefore intended to critically look at the successes and failures of Great Zimbabwe in terms of how the settlement pattern was, how it lasted as it could. Then it can be deduced that from the investigation to see the direction it took from inception to its fall. This leads us to the next question, how about the missing parts? What do they have to do with the investigation of the settlement? To answer these questions, we there is need to understand and investigate the morphology of this site, in this regard what morphology does is that it entails how the city was formed and how it worked a one organism, however what remains today are some of the remnants of that one organism, hence in order to understand the totality of it all the missing puzzle i.e. the missing parts has to be solved to completely know and understand the settlement morphology with the help of using the appropriate tool such as Artificial Neural Networks (ANNs) a branch of AI combined with GIS. From this investigation, it would then be deduced to find out how that city thrived in sustaining its occupants.

The expected results from the research are threefold: (i) Creation of an innovative strategy based on AI, Genetic Algorithms and GIS for the analysis of the archaeological site, especially related on the pattern reconstruction, this is a ground-breaking strategy that intends to use statistical analysis and data modelling techniques to tackle the pattern reconstruction process.(ii) Application of this method on a relatively unknown archaeological site like the Great Zimbabwe area, This would give way for a new way of research on similar alcohological sites. (iii) Use the combined method of Drone technology, AI, GIS in an innovative way. Consequently, this would allow for new ways to analyze the Great Zimbabwe site in a more accurate and insightful way.

Key words: ancient settlement, great Zimbabwe, Artificial intelligence, GIS, Pattern, Morphology.

3.0 State of the art.

State of the art is a phrase used to describe the most recent or current stage in the development of a product by using the newest ideas and features. Therefore, the state of the art in this proposal are the new techniques and ideas used to study the ruins for Great Zimbabwe. Therefore, when looking at the ruins of Great Zimbabwe one is faced with the remains of a civilization with a long history whose exitance is evidence that there once existed a society whose physical form (pattern) today seems more elaborate than the forms of some other African societies (in terms of spatial organisations [the pattern]) that existed in other places and those that still exist today (Kaarsholm, 1989). Indeed, more evidence of elaborateness is this civilization is shown in some Portuguese documents which associated the site with gold production and long distance trade in the 16th and 17th century, however with the coming of carbon dating the then state of the art technology, great Zimbabwe flourished even before the 16th and 17th century (Garlake, Peter, 1973). The state of the art in this proposal is twofold; (i) the incorporation of Unmanned flying vehicles (UAVs) or drones as an ongoing tool for aerial and spatial analysis (Org, 2018). UAVs are fit for going noticeable all around and navigating places that a human cannot. Their capacity to acquire pictures that incorporate enormous and small territories, is the UAV's primary and most utilized characteristic (DroneZon, 2018). Therefore, this characteristic of UAV's is that they are of a quality that they are advanced in nature and relatively reasonable in cost compared to remote sensing or aerial photography. To this effect, UAVs in the context of their use being applied to the investigation of the great Zimbabwe ruins site would be more flexible to maneuver around the site and be able to capture or map it within a short period of time. (ii) secondly, the other state of the art component for this proposal is the definitiveness of information obtained by UAVs and how it can be conceivable to utilize this data in further studies in relation to the topic of this proposal, is by combining this technology (drones) with artificial intelligence and GIS to investigate archaeological site. This would then result in Creating the original features and forms[3], of the missing parts in question, according with the left relics[4].

---

[3] In this case the pattern of the ruins.

[4] Hence the search for the missing parts would be found by using AI with the already existing relics. This is the innovative point.

4.0 Bibliography

Bach, J. (2009). Principles of Synthetic Intelligence: Psi: An Architecture of Motivated cognition. Oxford press.

C. R. (Ed.). (2017). Great Zimbabwe: The History and Legacy of the Medieval Kingdom of Zimbabwe's Capital.

Prasad, N. R. R. (2014). Neural Networks and Fuzzy Logic. Fuzzy Systems, 1997(April 1997), 381–401. https://doi.org/10.1007/978-1-4615-5505-6_11

Carpenter, G. (1991). Neural network models for pattern recognition and associative memory in G. Pattern-Recognition by Self-Organising Neural Networks,1-33. Cambridge, Massachusetts.: MIT Press.

Ginsberg, M. (1993). Essentials of Artificial Intelligence. Margan Kaufmann publisher.

Garlake, Peter, S. (1973). Great Zimbabwe. London.

Eastman (Ed.), C. M. (Ed.). (1975). Spatial Synthesis in computer-Aided Building Design. Willey.

Müller, V. C. (ed. (Ed.). (2016). Fundamental issues of artificial intelligence. Springer.

Kaarsholm, P. (1980). THE STRUGGLE OF COMPETING NATIONALISMS OVER HISTORY.

Reeler, C. (1999). Neural Networks and Fuzzy Logic Analysis in Archaeology, 750(April1997),108. Retrieved fromhttp://proceedings.caaconference.org/files/1997/CD-ROM/reeler1/REELER1.HTM

Patrick Olivier, Keiichi Nakata, M. L. (auth. (1996). Artificial Intelligence in Design '96. (F. S. (eds. John S. Gero, Ed.). London: Springer.

Conejo R. (ed.), U. M. (ed. (Ed.). (2004). Current Topics in Artificial Intelligence. Springer.

Mitchell, M. (1998). An Introduction to Genetic Algorithms (1st ed.). MIT Press.

Juval Portugali, Han Meyer, Egbert Stolk, E. T. (Ed.). (2012). Complexity Theories of Cities Have Come of Age: An Overview with Implications to Urban Planning and Design. Springer.

Pikirayi, I. (2016). Great Zimbabwe in Historical Archaeology: Reconceptualizing Decline, Abandonment, and Reoccupation of an Ancient

Polity, Great Zimbabwe in Historical Archaeology: Reconceptualizing Decline, Abandonment, and Reoccupation of an Ancient Polity.

Abdi h., Valentin d., E. B. (1999). Neural Networks. Sage University Series, (Newbury Park CA).

L., B. (1962). Archaeology as anthropology", American Antiquity, XX–VII, 2, 217–225.

DERAVIGNONE L., M. G. (2006). From GIS to Artificial Neural Networks: ten-year studies on fortified villages in central Italy. In Atti del convegno Archologie and Computer 2005, Workshop 10. Vienna.

E., H. (1997). MN/Model: an archaeological predictive model for Minnesota. In Proceedings of ESRI International User Conference.

DroneZon. (2018). 10 Best Photogrammetry Software For 3D Mapping Using Drones, 1–29.

Org, T. O. (2018). 4 Open Source Drone Projects. Retrieved from https://opensource.com/article/16/12/drone-projects

Nilsson, N. J., Science, C., International, S. R. I., Science, C., & Intelligence, A. (2010). The Quest for Artificial Intelligence A History of Ideas and Achievements. New York: CAMBRIDGE UNIVERSITY PRESS.

Walicki, J. (2019). Program a Tello drone to take pictures and then classify the images.

Searle, J. R. (1980). Minds, Brains, and Programs, Vol. 3, (Behavioural and Brain Sciences,), 417–457.

Great Zimbabwe HISTORICAL CITY, ZIMBABWE. (n.d.). Retrieved from https://www.britannica.com/place/Great-Zimbabwe

Deravignone l., Blankholm h.p. (2013). Grosseto Predictive Modelling Manual for ArcGIS. Retrieved 11 July 2019, from https://www.researchgate.net/publication/258283865_Grosseto_Predictive_Modelling_Manual_for_ArcGIS

Russell, S., & Norvig, P. (2010). Artificial Intelligence A Modern Approach (3rd Edition). (Third Edit). New Jersey: Pearson Education, Inc.

Deravignone, L. (2019). Geographical analyses and artificial intelligence for the study of late medieval settlements in Southern Tuscany, Italy.

Deravignone, L., & Macchi Jánica, G. (2006). Artificial Neural Networks in archaeology. Archeologia e Calcolatori, (17), 121–136.

Pijanowski, B., A Shellito, B., Bauer, M., & E Sawaya, K. (2001). Using GIS, artificial neural networks and remote sensing to model urban change in the Minneapolis-St. Paul and Detroit metropolitan areas, 26.

Gopal, S. (2016). Artificial Neural Networks in Geospatial Analysis. International Encyclopedia of Geography: People, the Earth, Environment and Technology, 1–7. https://doi.org/10.1002/9781118786352.wbieg0322

World Bank. (n.d.). Sub-Saharan Africa. Retrieved from https://data.worldbank.org/region/sub-saharan-africa.

5.0 Project description

Great Zimbabwe is an intricate structure of stone-walled structures located in south-central Zimbabwe (20°16′ 23″ S, 30° 56′ 04″ E)('Great Zimbabwe Historical City, Zimbabwe', n.d.). Its origin dates back from the early second millennium A.D. The site covers an area of more than 700 ha.
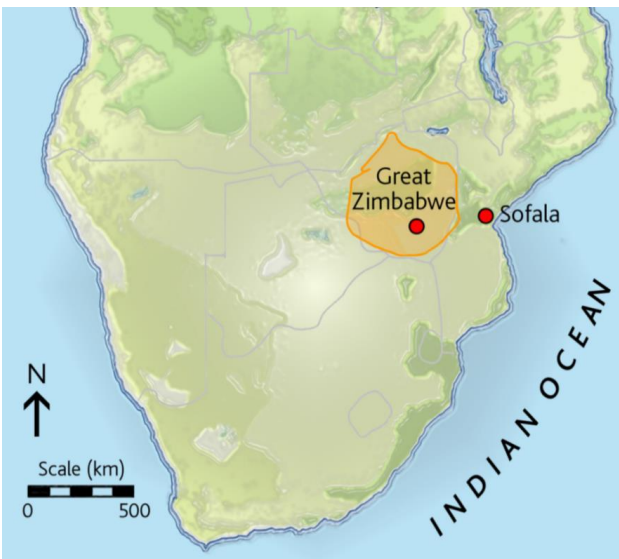
(a). Great Zimbabwe.
© The British Museum

(b) . Southern Africa.
© The British Museum

(c) great Zimbabwe aerial view.
© The British Museum

Figure 2.

Great Zimbabwe, ruins.

The site is also comprised of enormously built stone monumental architecture artefacts. This vast kingdom consists of hills, enclosures and valley ruins. According to estimates the central ruins supported a population of 10000 to 20000 people (Pikirayi, 2016).
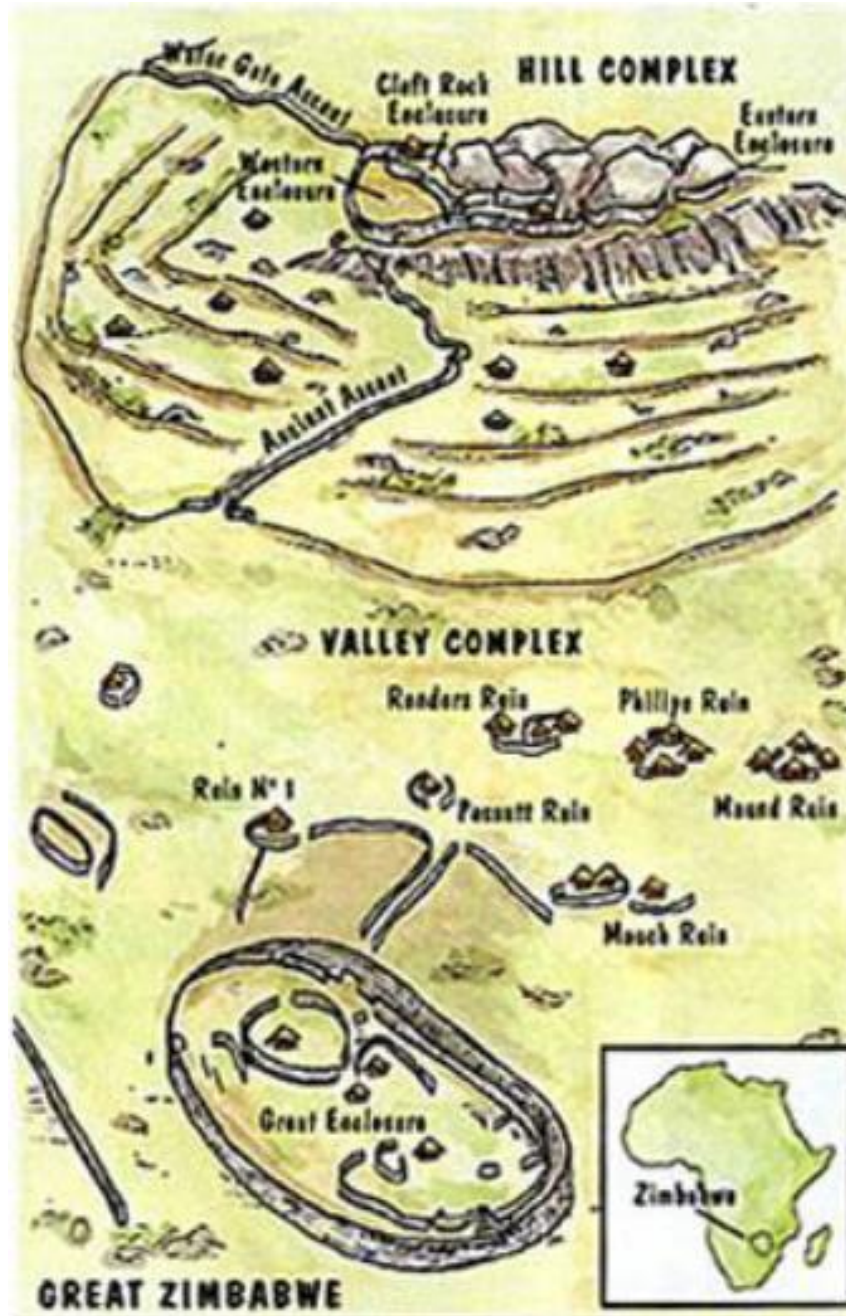
Figure 3.

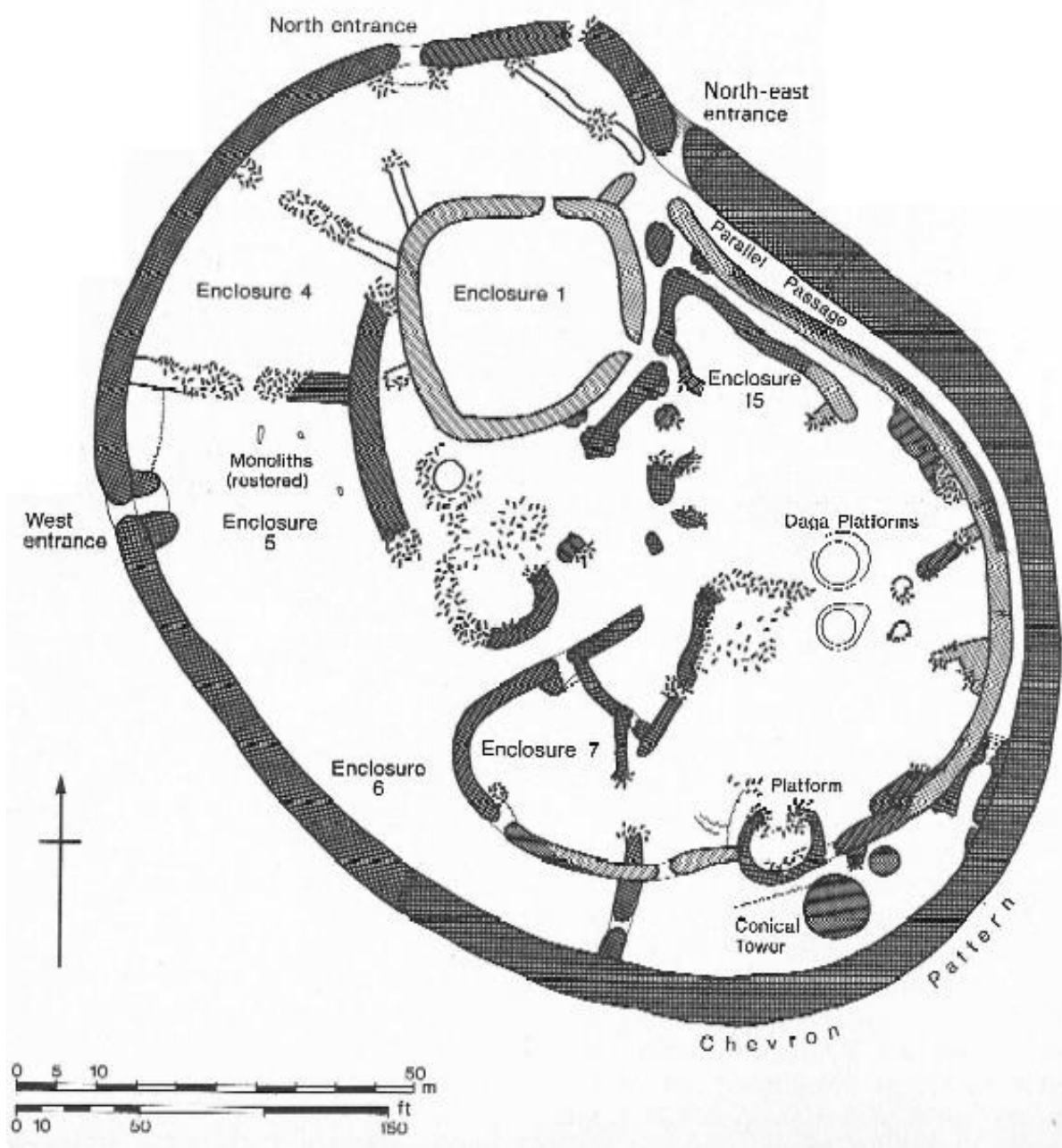Ruins of Great Zimbabwe (hills, valleys and enclosures)

© Lynda D'Amico

Figure 4.

the great enclosure.

(a)

(b)

(c)

(d)

Figure 5.

The great Enclosure, architectural and archaeological artefacts.

Source: Zimbabwe tourism.

This proposal presents a methodological approach based on how to use Artificial Intelligence combined with geospatial analysis (GIS) to analyse the ancient settlement layout (the great enclosure) pattern of great Zimbabwe. The aim is to introduce new aspects for a better comprehension of the settlement dynamics and, at the same time, to try to analyse physical planning patterns that at first glance appear to be unclear(Luca Deravignone, 2019). Therefore, the reason to understand the pattern is to know the relationships between human settlements (great enclosure) and its territory (hills and valleys) under an interdisciplinary study in the areas of architectural and arachnological approaches[5] . Furthermore, comprehending settlements patterns is also a step ahead for the understanding of society (L., 1962). Therefore, AI can usually help in the comprehension of the settlement pattern itself, as evidenced in the last two decades, the use of artificial intelligence based approaches has increased to a higher level in several disciplines and in particular Artificial Neural Networks (ANNs), which is one of the most successful applications in several areas (Abdi H., Valentin D., 1999). ANNs present various aspects suitable for geographical and archaeological research, thus, applying these methods through a spatial approach makes it possible not only to engage the problem from different perspectives and to observe the invisible relationships between human settlements and their location, but also to highlight the relationships between different kinds of settlements [6] (see figure below for relationships).

---

[5] At this point the idea is to combine the archaeological and architectural spatial planning approach.

[6] In the case of Great Zimbabwe, it can be observed that the kingdom was divided into several parts, thus AI can be used to analyse how they relate to each other. Furthermore, the analysis can also be in comparison with present day settlements. Another aspect to look at this analysis would to also look at it in relation to other places or sites in the southern Africa region as a whole.
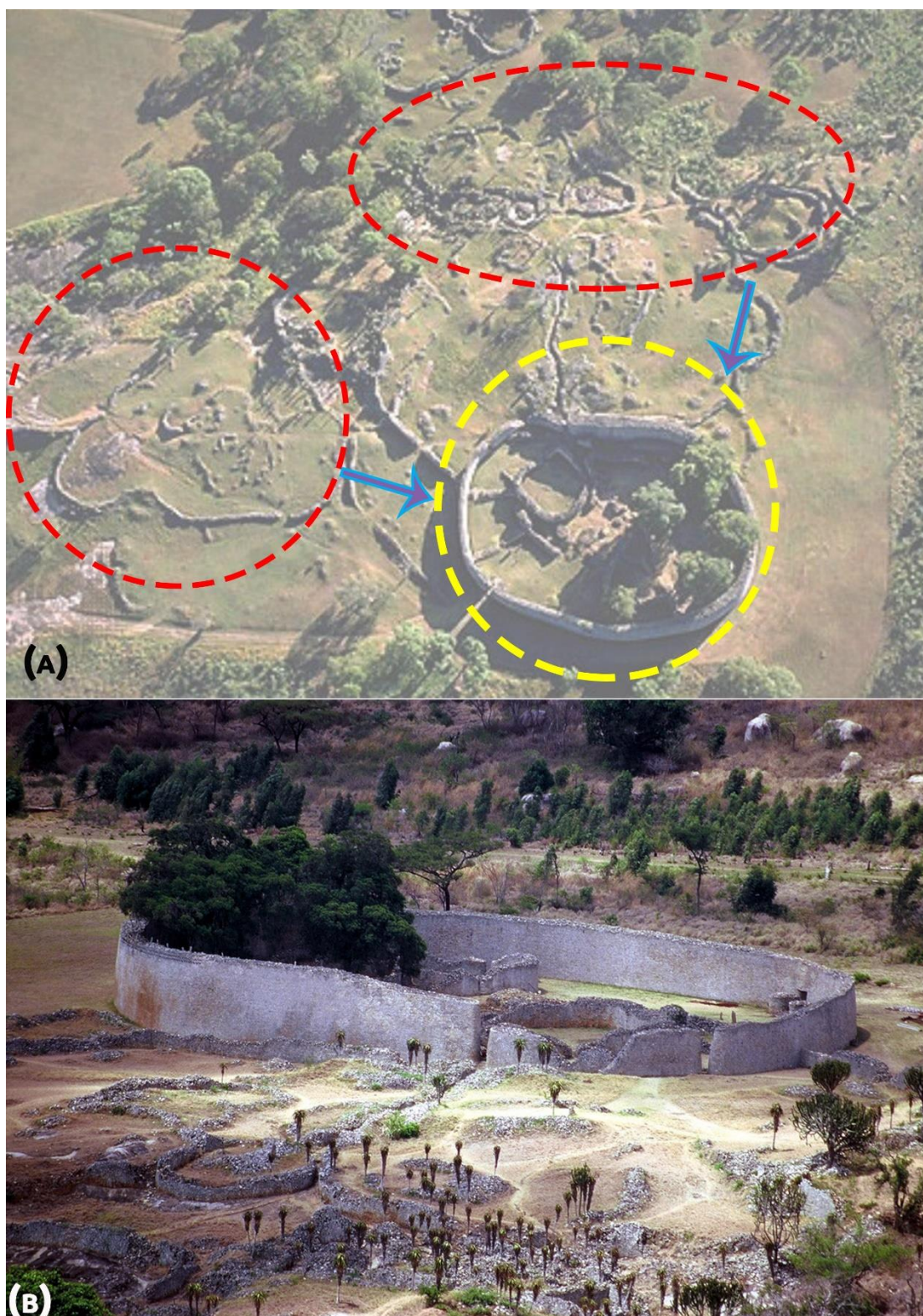
Figure 6.

The proposed study of the relationship of the great enclosure settlement and its
surrounding areas.

To be more explicit, this proposal concentrates on using ANNs to be applied on several problems of archaeological and geographical themes and in this case a double approach has to be investigated: (i) the creation of maps on one hand, (ii) and the analysis of the maps using Geographical information Systems (GIS) software i.e. ArcGIS or QGIS[7] which the author is familiar with, then finally the use of AI via ANNs as the final output for analysis or vice versa.
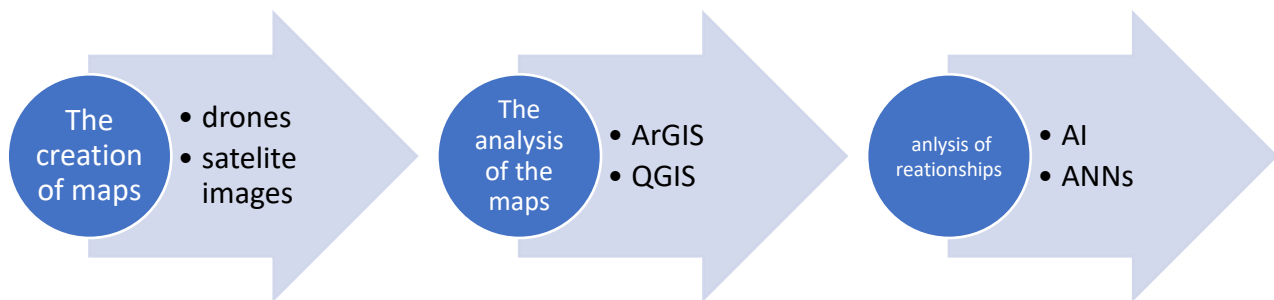

Figure 7.

A proposal of the methodological approach on how to use Artificial Intelligence combined with geospatial analysis (GIS).

Source: Author.

For example, one of the possible pattern analysis methods is the use of the hotspot analysis[8] in which the site is classified into regions showing the

---

densely populated areas (called hotspots) and regions of less densely populated areas (see figure below).
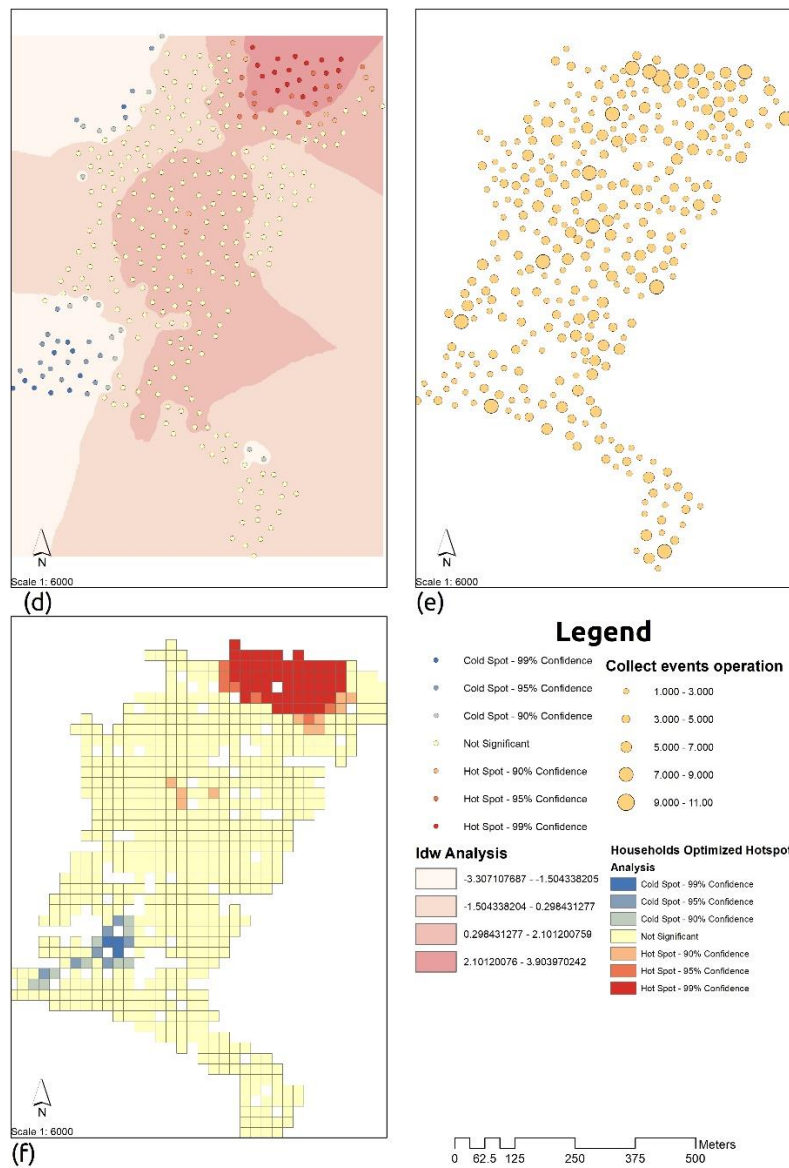

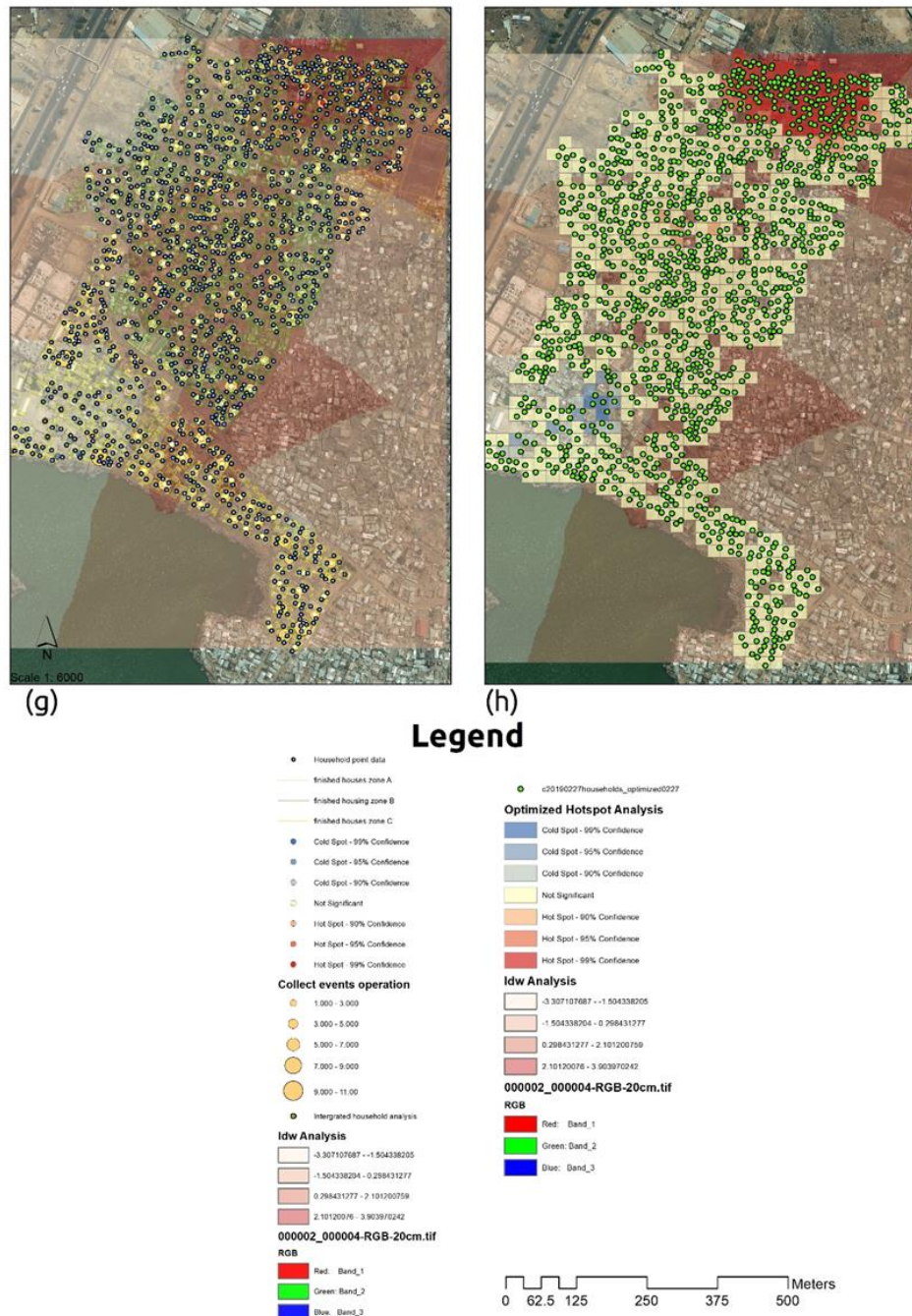Figure 8. hotspot analysis.

Source Author.

Figure 8.

hotspot analysis showing population pattern of settlement in terms population density.

Source Author.

The aim to use of AI with ANNs after GIS analysis is to reach the goal for the analysis of the ancient settlement patterns distribution identification and secondly for the identification of the missing parts (Luca Deravignone, 2019).

The ANN issue that still needs to be addressed here is "how to do?"[9]. Therefore, the first task is to determine the tools needed tools required for the use of ANN to be applied to spatial analysis using GIS. Previous research has been conducted by using an ANN simulator called Stuttgart Neural Network Simulator (SNNS) used for the study of medieval villages in Italy (L. Deravignone & Macchi Jánica, 2006). Remarkably enough, this an open-source software which is flexible to be used on almost any computer. Therefore, it very much possible to carry out by using the analysis from the following steps recommended by (L. Deravignone & Macchi Jánica, 2006) aimed to combine both ANN and GIS using the steps shown in table 1 [10].

Table 1.

five step analysis of using an ANN based software combined with GIS for settlement pattern analysis. Source: (L. Deravignone & Macchi Jánica,2006)

	Steps		Application
1	Creation of the training pattern file		Patgen
2	Network training		SNNS
3	Creation of a matrix data file		Asc2tab
4	Process the matrix with trained network		TTSR
5	Reconversion in raster format		Txt2asc

The table above entails that the steps taken to reach the goal of combining AI and ANN require basic Knowledge on the mentioned software and plug-ins[11] , therefore the innovation point here is how to used these software's to come up with conclusive results. For example, Patgen is a command line to

---

[9] Just as the hotspot analysis in the previous research, the results came as a result of rigorous testing of different methods and techniques to reach the goal. The same applies for this research ANN is just the start point for the pattern analysis of the ancient settlement. Therefore, the "how to do" should not necessary be restricted to AI and ANNs but other avenues of research discoverable by a deliberate and intensive search for Knowledge on the best possible way to tackle the research topic.

[10] It should be noted that the author has taken careful consideration in terms of the innovation point i.e. the use of AI in this proposal, thus the danger here is to ride on the works of (L. Deravignone & Macchi Jánica, 2006), which is not the intension of this research but to develop a method that would work in the context of great Zimbabwe.

[11] Most of which are open source software.

run SNNS[12] for pattern analysis, whose results are eventually interpreted using GIS.

6.0 Expected results

What is expected of this research proposal is to have results that will achieve the following:

A)   Creation of an innovative strategy based on AI, Genetic Algorithms and GIS for the analysis of the archaeological site, especially related on the pattern reconstruction.

The combination of using AI and Generic Algorithms and Geographical Information systems (GIS) is a ground-breaking strategy that intends to use statistical analysis and data modelling techniques to tackle the pattern reconstruction process. This is to be achieved by maximizing the use of artificial neural network (ANN) a branch of artificial intelligence that has the capacity and ability to work on complex data such as that regarding archaeological sites. In this case ANN would take up the challenge to be used for the pattern reconstruction of the missing parts in the ruins of Great Zimbabwe(Bailer-Jones, Gupta, & Singh, 2001).

B) Application of this method on a relatively unknown archaeological site like the Great Zimbabwe area.

Indeed, this method as mentioned in section (A), would be the "litmus test"[13] for the use of Artificial Intelligence and its capabilities of dealing with a site that has the slightest information in terms of its pattern available. This would pave way for a new way of research on similar alcohological sites faced with the same challenge of the lack of data.

C) Use the combined method of Drone technology, AI, GIS in an innovative way.

Integrating Drone technology with GIS under the umbrella of AI allows for new ways to analyse the Great Zimbabwe site in more accurate and insightful way. This method would also be the key to the use of advance capabilities of collecting, analysing and envisaging spatial and location-based data to have far reaching benefits in other fields. Furthermore, the results of the advancement of drone mapping technologies reinforced by AI would great a better platform for collecting high resolution spatial data that is efficient.

---

[12] According to the process SNNS is more of a self-learning software in which the researcher can input the parameters to teach it on what areas to look for. Perhaps the innovative point in this part of this proposal is to come up with parameters which will be suitable for the pattern recognition and analysis section.

[13] This is a decisive indicative test to prove that AI is capable of doing (pattern reconstruction) so on such a site that is relatively has not been studies on in such a manner.

7.0 conclusion

This proposal is to be understood by studying the pattern of the ruins of Great Zimbabwe's layout. Indeed, every pattern has a story to tell, the reason to look at the pattern is to understand the logic behind that kind of pattern, how it has developed and on what basis it was developed. The critical question also on this quest of the existence of the pattern is to ask for what is being looked for in this pattern, specifically in what context should this pattern analysis be based. Indeed, the pattern in question is the ancient settlement physical layout itself. Thus, the starting point of this pattern investigation is the home arrangement, how the space from the home transitioned to public spaces be it commercial or recreational. Thus, the quest in pattern seeking is to find out how the home (private space) related with the public spaces and how everything worked as one. The next question that now arises is that, "could ancient settlements tell us about how to tackle our current human settlement predicament?". Therefore, the ancient settlement of Great Zimbabwe in this proposal will be looked at as a casing point to seek answers to the predicament being faced in sub-Sahara Africa as a whole. Now, indeed the question that remains is, "what is this dilemma that current cites are facing, for there to be a need to look to the past for answers?" The dilemma is in part known and in part not certain because more effort needs to be taken through rigorous research and statistical analysis to get substantial evidence. The idea of using the ancient settlement is to see if the impact of the results gotten from the study on Great Zimbabwe, would have an influence on some of the urban problems faced in the cites, then an experimentation will be conducted to seek for solution of how the ancient cities tackled these problems. For example, Africa as well as Asia are faced with the problem of tackling overcrowding which has led to so many depravities in informal settlements or slums (UN-habitat, n.d.) . In order to curb this dilemma, it is pertinent that we seek answers from the ancient settlement to see how it could have solved such a crisis as well as many other crises faced in today's cites.

SIGNED

KEZALA JERE

08/08/2019