

## Estimating the Size of Human Settlement of Bujang Valley, Kedah Using Geographic Information System

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### ABSTRACT

*Archaeological evidences showed that Bujang Valley in Kedah was once a port that controlled trade between China and India between the 4<sup>th</sup> Century and the 14<sup>th</sup> Century AD. However, little evidences were found that could relate the local people with socio-economic and established trade systems. This study aims to use Geographic Information System (GIS) to investigate pattern and estimate the size of human settlement during its golden era. The study found that ancient settlements were clustered in close proximity to rivers which were used as a mean of transportation and water supply. The extend of human settlement was confined surrounding existing sites assuming that the movement was based on foot mainly due to physical barrier of the sites. The finding provides clue on the size of settlement and area of interaction between human and its environment in Bujang Valley, Kedah. This result could potentially be used at the early stages of the study prior to undertaking excavation of the area.*

*Key words: site-catchment analysis, pathdistance, Bujang Valley, point pattern analysis, geographic information system(GIS)*

### ABSTRAK

*Bukti-bukti penemuan arkeologi menunjukkan bahawa Lembah Bujang di Kedah merupakan sebuah pelabuhan yang mengawal perdagangan antara China dan India di antara abad ke-4 hingga abad ke-14 Masihi. Walau bagaimanapun, tidak banyak bukti yang ditemui yang boleh mengaitkan masyarakat tempatan dengan sistem sosioekonomi dan perdagangan. Kajian ini bertujuan menggunakan Sistem Maklumat Geografi (GIS) bagi menyelidiki corak dan menganggarkan saiz petempatan masyarakat tempatan pada zaman kegemilangannya. Kajian ini mendapati petempatan masyarakat zaman dahulu berkelompok berdekatan sungai yang digunakan sebagai jalan pengangkutan dan sumber air. Keluasan petempatan manusia berkisar dalam jarak yang boleh dihubungi dengan berjalan kaki disebabkan halangan fizikal tapak. Dapatan ini memberikan gambaran tentang keluasan petempatan dan kawasan interaksi manusia dengan persekitarannya di Lembah Bujang, Kedah. Hasil ini berpotensi digunakan pada peringkat awal kajian iaitu sebelum usaha ekskavasi dilaksanakan.*

*Kata kunci: GIS, analisis zon tadahan, pathdistance, Lembah Bujang, analisis corak titik, sistem maklumat geografi*

### INTRODUCTION

Archaeological sites represent the evidence of human activities in the past. The evidences which is in the form of postholes and moats that are not transferable or artifacts such as beads and stone tools that are transferable are the most essential resources to link present society to human existence in the past (Usui et al. 2006). It should be noted, however, excavations are usually time consuming and costly. In addition, natural environments and its elements are an important component in archaeology where it is used in such a way as an understanding aid in the determination of whether apparent associations in artifacts assemblage are the results of cultural pattern and natural phenomena (Tsumura 2006; Nik Hassan Shuhaimi Nik Abdul Rahman 2008). Although artifacts provide evidences from

the past, these observations are too scant, which makes it difficult to relate the observations to processes that might have occurred in the past. In addition to that, archaeological data is static in the sense that it exists at a particular form and place. Furthermore, such data does not point to specific relationship between cause and effect (van der Leeuw 2004).

Archaeologists, therefore, used various approaches in understanding how humans used their space and environment in order to make a living. Point pattern analysis, for example, can be used to evaluate the distribution of archaeological sites. This analysis provides clue on the characteristics and distribution of the sites. Point pattern analysis was usually used to measure whether the phenomenon such as disease or crime was systematically organized or structured compared with the

phenomenon distributed at random (Longley et al. 2011; Levine et al. 2009; Moore & Carpenter 1999). In describing the distribution of archaeological sites, nearest neighbor index (NNI) could be calculated to analyze spread of sites, where it calculates inter-sites distances to develop impressions of the strength of the clustering of point data. The value of NNI ranges from 0 and 2.1491, where the value of 0 shows that the distribution is clustered, 1 is random and the value of 2.1491 shows uniformed distribution (Robinson 1998). NNI, therefore, can easily be calculated and used in understanding the distribution of the sites. This approach, however, is being criticized for its failure to distinguish between homogenous and random pattern and it is heavily depended on the size of the study area (Moore & Carpenter 1999).

Another analysis is a site catchment analysis which is one of the approaches used to estimate the area extend of a settlement based on environment and physical characteristics of the area. It can be defined as the examination by survey, excavation, maps, and graphs of a contained area to evaluate the productivity of the resources customarily exploited by the inhabitants of a settlement, especially a prehistoric one (Christopherson et al. 1999; Narimah Samat et al. 2010). Assuming that the settlements were not randomly located across the landscape (van der Leeuw 2004; Narimah Samat et al. 2008), their selection was based on maximizing use of space and minimizing effort in gathering foods (Tsumura 2006). Therefore, by analyzing the mode of travel among its inhabitants, archaeologists tried to identify the space they would be able to exploit and use (van der Leeuw 2004). Traditionally, site catchment was measured based on Euclidean distance, travel time, and natural boundary (Christopherson et al. 1999). Euclidean distance is calculated based on straight line between two points. It is used to determine distance by creating a circular buffer zone at specific distance around a site (Longley et al. 2011; ESRI 2006). This method does not take into consideration natural barrier such as valleys or ridges around the sites (Burrough & McDonnell 1998; Christopherson et al. 1999). Natural boundary, on the other hand, determines catchment zone based on natural phenomenon such as mountain range, watershed or valley. In archaeology, this approach can easily be used since many archaeological sites were located within clearly defined physical boundary where settlements were usually located along rivers and streams (Jennings & Craig 2001; Allen 1988). This approach, however, lacks the information regarding

the social and economic activities of the zones (Tsumura 2006). Therefore, a scientific method of predicting area coverage of ancient cities would be useful for archaeologists in understanding socio-economic and culture of the past. Such approach, however, requires huge amount of information ranging from physical and cultural characteristics of the ancient settlements (van der Leeuw 2004).

Geographic Information System (GIS) which has the capability to manage and analyze spatial and attribute data becomes a useful tool for archaeologists who most of the time deal with spatial and attributes data of the sites and its characteristics (Burrough & McDonnell 1998; van der Leeuw 2004; Okabe 2006). This technology is able to handle huge amount of information and helpful in spatial data acquisition and management, analyze and predict the location of archaeological sites or simulate the extend of ancient settlement and visualization (Tsumura 2006; Usui et al. 2006). In the study conducted by Jennings and Craig (2001), for example, GIS had been used to establish the relationship between site location and the economic activity. Such analysis allowed researchers to predict social-culture activities of the ancient community. The study conducted by Clement et al. (2001), for example, used GIS to predict archaeological sites in South Carolina, USA. Data such as floodplain, hypsographic, and Digital Elevation Model (DEM) were used to predict the potential location of the archaeological sites. Furthermore, that model allows some prediction about known sites from which insufficient data was available for assessment and excavations (Okabe 2006).

GIS provides framework for integrating data from various sources, format and time periods (Burrough & McDonnell 1998; Longley et al. 2011), which allows analysis to be conducted on archaeological data. The study conducted by Kato et al. (2006), for example, integrated data from census, household-survey and geographical data to evaluate migration pattern, regional diversity and residential development on the edge of Cairo, Egypt. Micro data based on household survey was combined with digital map data to examine settlement pattern and regionalization among migrants based on region of origins. GIS capabilities allowed various types and forms of data to be integrated and analyzed in solving geographical problems. This technology, therefore, becomes powerful tool in assimilating knowledge and assisting to comprehend the patterns and process that might have occurred a long time ago (Tsumura 2006)

In understanding human settlement pattern, geographers had used Christaller's central-place theory which used location of service centers, even in nonmarket based societies, as the center of the people that use them (Smith 1976: 7 as cited from Jennings & Craig 2001). The optimal location of the administrative centers was likely to be located at the center of the settlements. Jennings and Craig (2001), however, argued that the location of the administrative centers of the ancient settlements was at the margin of the valley in order to function as a gateway that control interregional exchange. Allen (1988) for example, had conducted geoarchaeological survey on 87 historical sites in Kedah and used real distance to determine the population shift in this area. The findings suggested that Bujang Valley in Kedah was once an ancient port which lost its importance with time mainly due to changing of landscape caused by upslope erosion and redeposition in the main estuary. However, not much evidence was found on socio-economic activity of the communities. Therefore, not much conclusion can be made on local community that involved in trade and culture of the traders. However, archaeological evidence suggested that traders stopped at this port during inter-seasonal monsoon and built temporary *chandi* or temples for worshipping (Allen 1988; Mohd Supian Sabtu 2002). Thus, it is believed that this area did trade with traders from India, China and Arab and provided food and other supplies for the traders in exchange of good such as beads and stoneware's (Lamb 1982).

The area may not be able to sustain a large number of population. Furthermore, a major population shift appeared to have followed the blocking of a major estuary with silts, created vast floodplain which becomes irrigated rice growing areas today (Allen 1988). The major food sources were from short-fallow dry land cereal agriculture and from nearby jungle (Allen 1988; Nik Hassan Shuhaimi Nik Abdul Rahman 2008). Thus, it could be concluded that the settlement of this area would not be wide and limited to areas that could be reached on foot. It would be useful to predict catchment site, an area that might be reachable on foot in order to understand the interaction zones of the community. This information is useful since in archaeology the data were rarely available to study the relationship between site location and the economic activity of the local people (Jennings & Craig 2001). GIS, therefore, can be used to establish such relationship by combining geographical characteristics of the sites and evidences found during excavation (van der Leeuw 2004). The geographical boundaries

of the sites were estimated and used as proxy measurement of local population movement within the areas (Jennings & Craig 2001; Mohd Supian Sabtu 2002).

## METHODOLOGY

This study evaluated spatial distribution of archaeological sites and estimated the size of settlement or catchment zones of Bujang Valley ancient settlement. First, the study gathered the information regarding the location and date of archeological sites from published literatures such as Allen (1988), Lamb (1982), Mohd Supian Sabtu (2002), Mohd Mokhtar Saidin (2005) and Nik Hassan Shuhaimi Nik Abdul Rahman (2008). Then, site visit was undertaken and Global Positioning System (GPS) was used to verify the location of sites obtained. The sites, wherever archaeological excavation and evidence were found, were recorded and mapped into ArcGIS 9.3 software (ESRI 2006). Then, the sites were grouped based on the time of its existence which could be divided into the 5<sup>th</sup> century AD, the 7<sup>th</sup> Century AD and the 11<sup>th</sup> Century AD. Although chronometric or relative dating would be desirable to explain the existence of each site, such data was not available for this study. Information gathered from the literature surveys was used to determine date of the sites. For example, as cited from Nik Hassan Shuhaimi Nik Abdul Rahman et al. (2008: 76) *Sungai Mas, functioned as an entrepot and a kingdom earlier than Pengkalan Bujang, dated early 5<sup>th</sup> Century AD*. Third, the study acquired other spatial data such as rivers and topography from Bujang Valley Archaeological Museum and Department of Survey and Mapping, Malaysia. Database was built in ArcGIS 9.3 software. All data were combined and converted into raster format with cell size of 100 m x 100 m which was determined arbitrarily. In evaluating spatial distribution of sites, NNI was calculated by using Spatial Analysts function of ArcGIS 9.3 (ESRI 2006). It was calculated based on nearest distance using  $d(s_i, s_j) = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$  where  $d(s_i, s_j)$  represents the distance between point  $i$  and  $j$ . This analysis provided information regarding the clustering of sites such that the inference could be made regarding the pattern of settlements in this study area. Then, site catchment was predicted for each date to represent the expansion of interaction zones in Bujang Valley. Finally, one site catchment

was produced by combining all existing sites in order to possibly view the boundary of this valley during its golden era.

In conducting site catchment analysis, *pathdistance* function of ArcGIS 9.3 was used, which can be used to calculate the cost of travelling up or downhill, and over vertical and horizontal barriers. Physical distance travelled was used as cost distance. This function also calculates, for each cell, the least-accumulative-cost distance over a cost surface from a source cell or a set of source cells while accounting for surface distance and horizontal and vertical cost factors (ESRI 2006). Catchment zone of the archeological sites was potentially be an area where local people could move about or interact with the environment in conducting daily chores or gathering and planting food for living (Christopherson et al. 1999). This study, therefore, used *pathdistance* function since this function is easily available in ArcGIS software to estimate the space used by the local community in Bujang Valley. This calculation was undertaken by taking into consideration of physical barrier namely topography and main rivers.

### STUDY AREA

Bujang Valley, Kedah is located at the south central portion of the state of Kedah on the northwest coast of Peninsular Malaysia between 100° 20'E and 100° 30' E longitude and 5° 32'N and 5° 38'N latitude. This coastal region is drained by two major rivers namely the Merbok and the Muda River, was once an important entrepot, transshipment points in trade or distributive exchange (Nik Hassan Shuhaimi Nik Abdul Rahman 2008; Jamaluddin Md. Jahi 2008). Figure 1 shows the location of Bujang Valley, Kedah and the distribution of sites where excavations were undertaken by various institutions. Archaeological evidences pointed to the existence of a flourishing import-export trade conducted at two peninsular sites namely Takupa in South Thailand, and Pengkalan Bujang in Kedah (Lamb 1982; Allen 1988). Furthermore, this area was an important landmark not only for Malay Peninsula but also for the Malay World (Mohd Mokhtar Saidin 2012).

Archaeological evidence indicated that this area played essential role in controlling trade and became gateways for exchanging goods in the Straits of Malacca between Malaya and other areas. Furthermore, the traffic in the sea of this region was pretty much coordinated with monsoonal direction (Nik Hassan Shuhaimi Nik Abdul Rahman &

Othman Mohd Yatim 1992; Mohd Supian Sabtu 2002). Bujang Valley, therefore became the coastal centre for layover points where ship's captains, merchants, and others passengers including religious pilgrims and priests stayed for prolong periods while waiting for seasonal shifts in the monsoon that would allowed them to continue their voyages (Lamb 1982; Allen 1988).

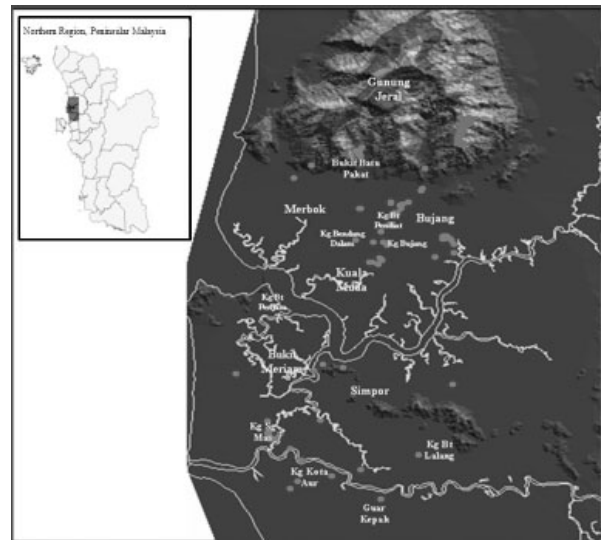


Figure 1. The study area - Bujang Valley, Kedah and location of its archaeological sites

Source: Lamb 1982; Allen 1988; Nik Hassan Shuhaimi 1988; Department of Survey and Mapping, Malaysia 1986

Bujang Valley was once an ancient city that is famous for being an entrepot as early as the 4<sup>th</sup> century. There is much evidence, archaeological findings that proves that Bujang Valley was a well-known, powerful city (Lamb 1982; Nik Hassan Shuhaimi Nik Abdul Rahman & Othman Mohd Yatim 1992). Therefore, many studies undertaken on Bujang Valley focused on archaeological findings such as the temples, monuments, decorative objects, beads and many more. From the excavation conducted by the previous researchers, the city of Bujang Valley is said to exist from the 4<sup>th</sup> Century up to the 14<sup>th</sup> Century (Nik Hassan Shuhaimi Nik Abdul Rahman et al. 2008). The settlements in this area revolved around Merbok River and Muda River and their tributaries, and were said to be built by the entering and leaving of the many merchants from many numerous country mostly of which are from India, China and the Middle Eastern countries (Allen 1988). The level of river is also said to have decline ever so slightly from time to time causing some settlements site to shift, being a rural

area (Sullivan 1958; Mohd Mokhtar Saidin 2005; Jamaluddin Md. Jahi 2008). Another point of view on the settlements and the spread of influence in Bujang Valley was that the visiting merchants built settlements on the highlands that were around the Gunung Jerai, Bukit Penjara and Bukit Batu Lintang. Lower altitude areas were then still covered by water, thus these hilly areas were perfect for a living and to carry out daily activities (Nik Hassan Shuhaimi Nik Abdul Rahman 2008; Jamaluddin Md. Jahi 2008). However, due to upslope erosion, Bujang Valley functioned as entrepot started to decline and lose its importance.

Even though many archaeological findings were found in Bujang Valley and many researches were carried out in this area, most if not all focused on the role of this ancient city as a famous entrepot (Allen 1988; Nik Hassan Shuhaimi Nik Abdul Rahman & Othman Mohd Yatim 1992). Many archaeological sites were found in Bujang Valley, where the earliest site found was in Sungai Mas that was believed to have started since the 5<sup>th</sup> Century (Lamb 1982; Nik Hassan Shuhaimi Nik Abdul Rahman 1988). Recent excavation by Universiti Sains Malaysia's archeologists, however, found that there was evidence pointed out that Bujang Valley was an important settlement since the 3<sup>rd</sup> Century AD (Sinar Harian 2009), which had established trade and socio-economic systems. The settlements then, was moved to Pengkalan Bujang and the surrounding areas. Evidence showed that many of the settlements revolved close to the main river that was the Merbok River and the Muda River, where the activities of trading took place. Based on archaeological findings this area was once a very important landmark for the Malay Peninsula.

The main reason for choosing Bujang Valley, Kedah for this study is that not much evidence on local community was found. Thus, the existence of local people in this valley was pretty much unknown except for the inference made. For example, pottery from China was associated with the barter system used to trade goods between the local and Chinese traders in the old days (Mohd Supian Sabtu 2002). Nik Hassan Shuhaimi Nik Abdul Rahman and Othman Mohd Yatim (1992) suggested that local people were food gatherers and traded with the traders from Arabs, India and China. Allen (1988), on the other hand, found that dry land cereal was the main food source of the local people. Based on those findings, this study attempted to estimate the size of settlement of Bujang Valley during its golden era. Such analysis would enrich this field and provide

a clue on the area that once might be used as settlements by local people.

## RESULT AND DISCUSSION

The analysis undertaken produced interesting results. Based on the location of sites mapped, point pattern analysis showed that sites were clustered with NNI of 0.53. Figure 2 illustrates the result obtained from this analysis. This result shows that in selecting the settlements, physical and environmental characteristics of the sites were important in order to ensure abundant food supply and water resource. Therefore, the settlements in Bujang Valley tend to cluster near Merbok and Muda Rivers and their tributaries (refer to Figure 1).

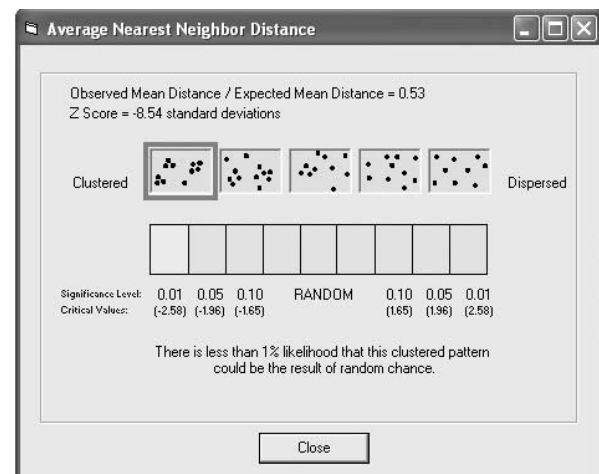
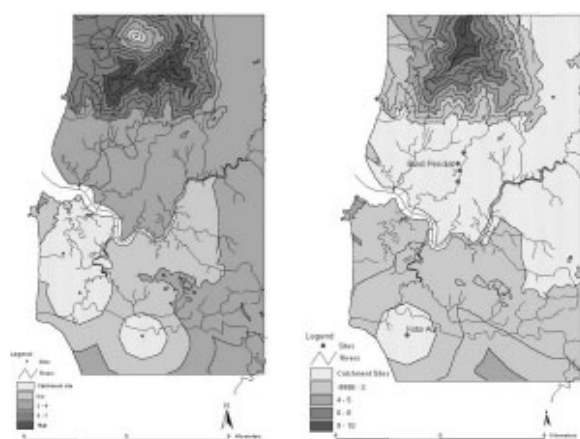


Figure 2. NNI index obtained from analysis undertaken using ArcGIS 9.3 software

The study then, estimated areal extent of Bujang Valley. As discussed earlier, sites were divided into four dates namely the 5<sup>th</sup> Century AD, 7<sup>th</sup> Century AD, 11<sup>th</sup> Century AD and combination of all (Nik Hassan Shuhaimi Abdul Rahman & Othman Mohd Yatim 1992). Based on the literature review, it was found that three main sites namely Sungai Mas, Bukit Choras dan Bukit Meriam could be dated back to the 5<sup>th</sup> Century AD (Nik Hassan Shuhaimi Abdul Rahman et al. 2008). Figure 3(a) below illustrates area extent of these sites. Darker color in this map represents level of difficulties to be explored. Zone with dotted pattern (brighter color) represents interaction zones during the 5<sup>th</sup> Century AD. Table 1 represents site catchment areas calculated. During the 5<sup>th</sup> Century AD, the area covered approximately 6669.3 hectares.

Barrier used such as topography and rivers limit the movement towards the north of the study area. The analysis conducted on the sites dated the 7th Century AD showed slightly bigger catchment zones (Figure 3(b)). This figure illustrates a bigger interaction zones since more sites or settlements were opened. It represented approximately 20,122.0 hectares surrounding Bukit Pendiati, Kota Aur, and Pengkalan Bujang (refer to Table 1).



(a) Sites dated 5AD. (b) Sites dated 7AD.

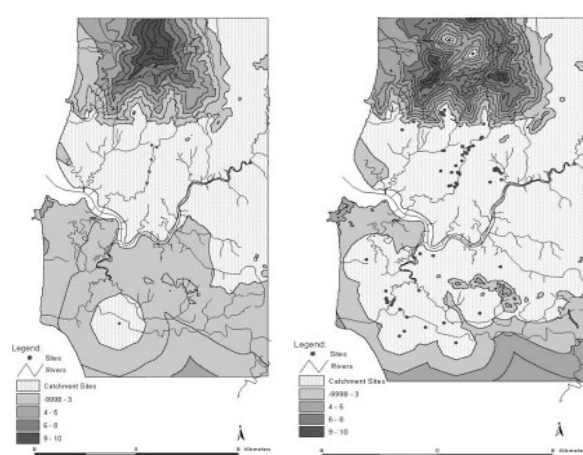
Figure 3. Site catchment calculated for the 5<sup>th</sup> Century and 7<sup>th</sup> Century AD at Bujang Valley, Kedah

Furthermore, the analysis was undertaken on sites found dated the 11<sup>th</sup> Century AD (Figure 4(a)). More sites existed during that period, which resulted in bigger catchment zones approximately 23739.8 hectares. Finally, the analysis was undertaken by combining all sites found in Bujang Valley. As shown in Figure 4 (b), bigger catchment zone was mapped, representing larger space was inhabited by local community. This was probably due to larger number of population settled in this valley. Since topography and rivers were used to measure barrier in the movement, not much changes could be found between zones created during the study period. An area of 32977.1 hectares was calculated indicated that as more people resided in this settlement, people required larger settlement zones. This finding also indicated that interaction zones increased slightly with time. Although only the interaction zone was derived to explain the interaction of local community in Bujang Valley, this analysis provided a different perspective in looking at archaeological data which is normally used to bridge gap between present and ancient community.

Table 1. Estimated areal extend of site catchment or interaction zones between man and environment in Bujang Valley, Kedah

Date	Area (Hectares)	Main centers
5AD	6669.3	Sungai Mas, Bukit Chora and Bukit Meriam
7AD	24122.0	Bukit Pendiati, Kota Aur, and Pengkalan Bujang
11AD	23739.8	Guar Kepah and sites located near Pengkalan Bujang
All sites	32977.1	All sites included

The study managed to estimate interaction zones among local community in the ancient city of Bujang Valley. It should be noted that topography used was based on topographic map produced by Department of Survey and Mapping, Malaysia (1986). In archaeology, data was limited, thus, this study provided an initial attempt to examine local community. Furthermore, archaeological excavation is time consuming and costly, and sometimes it is difficult to be undertaken because the sites was destroyed to give ways to development (Mohd Mokhtar Saidin 2005). Therefore, archaeologists had to rely not only on data acquired from excavation but also a scientific method of understanding culture and socio-economic of ancient people. This study, provided an initial attempt towards understanding some aspect of local land use especially in areas where archaeological evidence is limited (Christopherson et al. 1999).



(a) Sites dated 11AD (b) All sites found in Bujang Valley.

Figure 4. Site catchment calculated for the 11<sup>th</sup> century AD and all sites at Bujang Valley, Kedah.

Source: Lamb 1982; Allen 1988, Nik Hassan Shuhaimi 1988; Department of Survey and Mapping, Malaysia 1986

Although this study managed to estimate the extent of settlement of Bujang Valley, more research needs to be undertaken to assist in understanding human settlement pattern. This study could be extended by including agent-based and cellular automata model which could be used to undertake backward simulation by using present population in order to estimate the size of population of the past. Such analysis, however, proved to be challenging to be undertaken due to the limited amount of spatial data available on archeological sites in general and on Bujang Valley ancient settlement in particular.

## CONCLUSION

Bujang Valley, Kedah, which was once important trading and religious centers in the Malay Peninsula lost its importance due to physical and environmental factors and the competition from ports such as Malacca. However, not much evidence on local people could be found. This study, therefore, provided an attempt to estimate the size of settlement of local community. It was found that GIS analysis could effectively be used as an aid in understanding some aspect of human settlements for Bujang Valley between the 4<sup>th</sup> Century AD and 11<sup>th</sup> Century AD. Site catchment analysis managed to provide estimate of area extend of this ancient port during its golden era. This study could potentially be used to help archaeologist at the early stage of the study prior to excavation.

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