Evaluating the effectiveness of land-use zoning for the protection of built heritage in the Bagan Archaeological Zone, Myanmar. A satellite remote-sensing approach.

Dr Ben Edwards, Dr Tilman Frasch, Dr Julia Jeyacheya
Manchester Metropolitan University

This paper analyses the effectiveness of land-use zoning for heritage protection in the Bagan Archaeological Zone, Myanmar. Bagan is one of the most significant archaeological sites in the world for Buddhist built heritage, and was inscribed on the UNESCO World Heritage List in 2019. Beginning in the 9th or 10th centuries some 2500 religious monuments were built within the 60 square kilometre area of Bagan, a centre of kingship, Buddhist learning, and monasticism. Following a devastating earthquake in 1975 Burmese and international attention began to be paid to the reconstruction and conservation of the monuments at Bagan, but with mixed success. In this paper, publicly available satellite data is analysed to evaluate one of the important, but hitherto un-evaluated, elements of the local conservation regime – land-use zoning to restrict urban development. By measuring the expansion of urban areas within the Bagan Archaeological Zone from 1987 to 2018, in comparison with control settlements beyond the archaeological area, we conclude that a restrictive zoning regime has controlled urban sprawl, and aided the conservation of the setting of Buddhist monuments.

1. Introduction

In 1999 the Myanmar government approved and certified the zoning of land around the ancient Buddhist capital of Bagan, central Myanmar. In the context of a, now successful, attempt to have Bagan inscribed on the UNESCO World Heritage List, this zoning was designed to protect the 3388[1] monuments in the area from urban expansion and development. This paper evaluates the long-term effectiveness of the zoning policy, by measuring the expansion of urban areas within the Bagan Archaeological Zone using open-source satellite data from the USGS Landsat archive, and from the European Space Agency's Copernicus programme. Satellite imagery from 1987 to 2018, at four-year intervals, was analysed to measure the area of urban development before and after the implementation of zoning and, crucially, to compare this development with the nearby settlements of Chauk and Pakokku, which lie beyond the area of archaeological interest, and has not been subject to zoning. This paper aims to inform the ongoing management of Bagan as a World Heritage Site, by addressing a problematic absence in the evaluation of heritage management in the area: whilst great effort and expense has been directed at improving local policies on the conservation of individual monuments at Bagan, relatively little attention has been paid to urban development in area, which directly affects the character of the region's heritage sites.

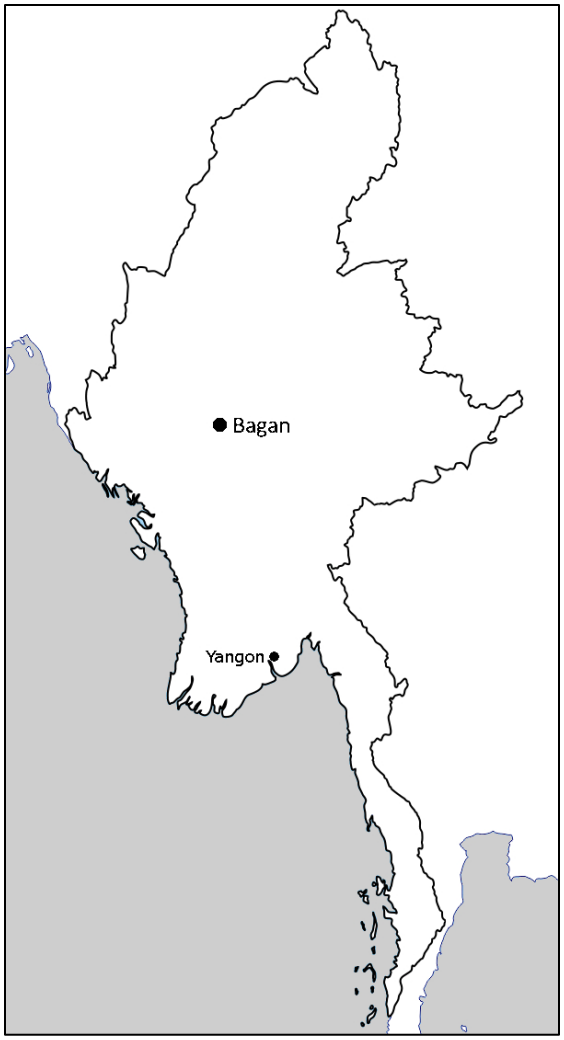

Figure 1: The location of Bagan

[1] Hudson 2008b: Bagan working database (accessed May 2013)

Bagan is one of the most significant archaeological and heritage sites in Myanmar and possibly in the world. Emerging around the 9th or 10th centuries CE, the city flourished as the political and cultural centre of the first kingdom in Myanmar until the end of the 13th century, when it was conquered and briefly occupied by Mongol invaders. During its peak period some 2500 religious monuments – chiefly Buddhist temples, stupas and monasteries – were built in and around the then capital on an area comprising some 60 square kilometres. As a centre of Buddhist learning, the Buddhists of Bagan and other parts of the kingdom had maintained close contacts with Sri Lanka, the alleged place of origin of Theravada Buddhism, from the end of the 11th century. In the course of time, the exchanges became part of a wider Buddhist ecumene, including India, mainland Southeast Asia, Tibet and probably China as well. By 1200, Bagan had become a Buddhist cosmopolis, where monks and laymen from all over this ecumene met, studied and held religious ceremonies. A large number of inscriptions in the Pali language, the lingua franca of Theravada Buddhists, attest to this multicultural and multilingual composition, as do the several monasteries at Bagan that were inhabited by Sinhalese monks. The presence of a Cambodian monk and references to a major convocation of the Buddhist sangha (monks' order) indicate that the city may also have played a crucial role in the transmission (or rather re-establishment) of the Theravada Buddhism in the late Angkorian empire (Frasch, in print).

The decline of Bagan as a political centre and its replacement with new capital cities in Upper Myanmar did not lead to a complete abandoning of the religious institutions, some of which are in fact known to have existed and received donations from the local populace or pilgrims until the end of the 14th century and beyond. In 1442, one of the biggest libraries ever to be donated in Myanmar was given to a monastery at Bagan (U Tin Htway & Luce 1976), and the city also became the destination of numerous royal visits until the 19th century. These visits often resulted in the sponsorship of restoration work, sometimes in direct response to the frequent earthquakes that shook central Myanmar (U Than Tun 1976; U Thawbita 1976). All these visits and resulting donations suggest that the whole area of Bagan catered for various forms of human habitation from the city's heyday in the 13th century to the present, comprising individual monks dwelling as hermits in the monasteries, villages such as Minnanthu or Taungbi, and of course the town of Nyaung-U, which served as the administrative centre for Bagan since the 15th century. Indeed, the very existence of these villages is probably the result of the establishment of satellite monasteries in the hinterland of Bagan proper from the late twelfth century, such as Pwazaw in the vicinity of the Dhammayazika stupa, completed 1198, and Minnanthu, where the first recorded monument dates to 1193.

2. Heritage Management at Bagan

Data-led heritage management at Bagan is a relatively recent development, starting in a concerted manner after an earthquake in 2016, not least because of the isolationist policies of the Myanmar government during the mid and late twentieth century, but also because of a lack of detailed knowledge on the number and complexity of the archaeological remains. A stimulus to the management of the physical remains at Bagan was an earlier major earthquake in 1975 (Hudson 2008a, 555), which damaged a large (but unrecorded) number of monuments. As part of an international response, coordinated by UNESCO, in 1982 Pierre Pichard was commissioned to produce the first inventory of the monuments present in the Bagan area – an enormous task, with the final volume published in 2002 (Pichard 1992-2002). Management efforts gathered pace during the 1980s, with an international symposium opening in Bagan in 1988 to discuss its study and preservation (Hudson 2008a, 556). This led to the production of a draft conservation plan for the area in 1989 (Pichard 1989), by which time UN had

spent nearly $1M through its development programme, repairing 150 monuments since the 1975 earthquake (Hudson 2008a, 555).

Burmese governmental responses to the management of Bagan during the late twentieth century were varied and in part delivered as part of a strategy aimed at inscription on the World Heritage List, although at least one policy arguably had a detrimental effect on the achievement of this aim. First, the wholesale movement of the settlement of Old Bagan, numbering some 5000 people and located within the medieval walls of the citadel, 5 kilometres south to New Bagan (Sanday 1992, 8). Despite some local evidence that not all local people opposed the forced relocation (Kraak 2018b, 122), this event is often cited alongside more general critiques of the human-rights record of the Myanmar regime (South 2007; Hudson 2008a, 557; Meskell 2015; Kraak 2017a, 2017b, 2018a, 2018b). The ethics of this decision are not the subject of this paper, though it is worth noting that in the aftermath of the relocation, hotel and museum development did again occur within the walls of Old Bagan.

Second, in 1995 the central government launched a campaign for public donations to fund the reconstruction of buildings and monuments at Bagan. This was highly successful and had raised approximately 1.3 billion Kyat by 1996 (U Nyunt Han 1996), and perhaps as much as $1M by 1998 (Hudson 2008a, 558), however, the quality of these reconstructions and the evidence upon which some were based has been heavily criticised (Messeri 2007, 4). Most structures ruined in the 1975 earthquake have now been reconstructed: 89% of temples and stupas according to an analysis of IKONOS satellite imagery by Bob Hudson (Hudson 2008a, 566). Yet this garnered significant international criticism, particularly those monuments reconstructed only from ground plans, or those which ignored an existing ground plan entirely. These problems were compounded by a lack of documentation of those sites that were subject to repair and reconstruction, and the use of inappropriate or low-quality materials (Yarmola 1992; Engelhardt 1995, 4), which degraded rapidly when subject to heavy rains (Engelhardt 1995, 6; Weise 2016, 75). Indeed, these concerns were proved well-founded by the collapse of recently reconstructed monuments during the 2016

Figure 2: Temple 1166, reconstructed in the late 1990s, destroyed in the 2016 earthquake

earthquake (see figure 2), whilst older monuments survived. In response to this criticism, further reconstruction was suspended in 2011 as it was endangering the achievement of World Heritage Site status (Kraak 2018b, 117). The situation is complicated, however, by the recognition that for many Burmese Buddhists these monuments are not passive heritage sites belonging to an era of the past, suitable only for veneration due to their historicity. In reality, these are *living* monuments with contemporary religious relevance, and thus their reconstruction (or indeed donating funds to aid in their reconstruction) is an important way to 'make merit' in the Buddhist tradition. Bringing these structures back into religious use is more important in this conceptual scheme than the authenticity of any reconstruction (Wolf 2000, 23).

In light of international criticism, following the 2011 suspension of reconstruction and the formation of the new Myanmar government under Thein Sein, restoration strategies shifted to closer engagement with external heritage experts and capacity-building of local professionals and institutions. One such project, subsidised by the government of Italy, focused on the technical capacity of local experts (Facchinetti 2014, 18), but also reached out to local people to engage them in the process (Rellensmann 2015), a priority repeatedly identified from as early as 1992 (Pichard 1992, 9; Higham 2001, 136). This aimed to improve the restoration and conservation of individual monuments, including friezes and wall painting, based on detailed recording and documentation through a combination of laser-scanning and photogrammetric modelling (Mezzino *et al.* 2016; Mezzino *et al.* 2017). The results of this ongoing process are also displayed to the public in the Bagan Archaeological Museum. Finally, international cooperation has also been undertaken in managing the pressure of tourism on the monuments. Whilst this is not the focus of this paper, it is worth noting the existence of the 'Plastic Campaign', funded by Nagata Co, a Japanese advertising firm as part of its corporate responsibility programme. Beginning in 2014, this saw the placement of litter bins throughout the Bagan Archaeological Zone in an attempt to manage the very visible problem of plastic waste, although the project has been criticised for lack of engagement with local stakeholders (Crabolu 2015, 30). The design of the bins is also unsympathetic to the local context and appear intrusive in the landscape.

Finally, it was the 2016 earthquake centred near Chauk, which provided further stimulus for investment in conservation and management at Bagan. This culminated in the first complete survey of natural and human induced risks to the cultural heritage of the area in the form of the *Bagan Disaster Risk Management Plan* (2018), published by the Ministry of Religious Affairs and Culture. In addition to the risks of damage from earthquakes and flooding, the document also listed building development as of 'medium risk' to physical cultural heritage, and restated the importance of the zoning policy in relation to direct physical damage to monuments and, importantly, their viewshed (*ibid*, 17, 21). The document also formed an important element in Bagan's nomination with UNESCO for World Heritage Site status. Additional work following the 2016 earthquake, in the context of WHS nomination, also included the creation of an integrated GIS database for management, and several guidance notes on effective conservation and stabilisation of the monuments at Bagan (Duong Bich Hanh 2018a, 6). These were submitted as part of the nomination in 2018 (Duong Bich Hanh 2018b, 10), and represented an area-wide strategy complementing the specific conservation efforts described above.

YEAR	BAGAN	NATIONAL CONTEXT
1975	6.5 Richter scale earthquake damages monuments	
1982	Pierre Pichard begins the inventory of monuments	
1988	Bagan Symposium opens	Martial law declared as Ne Win government collapses
1990	Old Bagan depopulated and moved to New Bagan	
1992	1st volume of Pichard's inventory is published	
1994	Bagan zoning first drawn up under Township Law	
1995	Government-led restoration begins	Government calls for public donations to restore Bagan
1996	Golf course established	Bagan inscribed on UNESCO Tentative List; Lift of visa restrictions for 'Visit Myanmar Year'
1999	Bagan zoning approved and certified	UNESCO announces $30,000 for the preparation of the Bagan management plan
2002	Final volume of Pichard's inventory published	
2011	Italy funds E400,000 UNESCO safeguarding project at Bagan	New government under Thein Sein and the beginning of the liberalisation of the Burmese economy
2012	Pakokku Bridge opens	
2014	First consultative meeting to prepare WHS application for Bagan	
2015	Heavy rainfall causes flooding, destroying 20 temples and damaging many more	
2016	6.8 Richter scale earthquake damages monuments	
2019	Bagan inscribed on the UNESCO World Heritage List	

Table 1: Important dates in the history of heritage management at Bagan, and their national context

Land-Use Zoning for Heritage Protection at Bagan

The principle government policy in the management of Bagan, however, was to emerge in 1994 under the Township Law and Order Council for Pagan-Nyaung-Oo Township (JICA 2014, 2-16), which established a hierarchy of three zones with correspondingly severe restrictions on the development of urban areas, buildings and infrastructure (see figure 3). This appears to have been born of recommendations for the production of a further masterplan for the conservation of Bagan by UNESCO

(Sanday 1992, 7; Nishimura 1994, 2). The zoning was approved at national level in 1999 (JICA 2014, 2-16). The 'Archaeological Zone' of Bagan was split into the 'Ancient Monument Zone', containing the densest concentration of monuments; the 'Ancient' or 'Ancient Site Zone', acting as a buffer around the Monument Zone; and the 'Protected and Preserved Zone', a large area mainly comprising the hinterland of Bagan with relatively few monuments (JICA 2014, 6-3). In the Ancient Monument Zone the construction of new buildings outside of existing settlements is essentially prohibited, and new roads must be relatively narrow; in the Ancient Site Zone construction is allowed provided it conforms to strict conditions on size and distance from monuments; in the Protected and Preserved Zone building is allowed provided permission is obtained and archaeological excavation is undertaken beforehand. Urban zones were also identified, largely corresponding to the limits of existing settlement, and therefore restricting the space for potential future development. Similarly, hotel zones were established, mainly in the area between Nyaung-U airport and the town, as well as areas beyond the edges of the Protected and Preserved Zones.

Criticisms have been levelled at the effectiveness of this regime in specific cases. Of particular concern is the construction of large and intrusive buildings in the Ancient Monument Zone: the Bagan Archaeological Museum, a particularly large and imposing structure modelled on a Bagan-era palace, and the Nan Myint viewing tower, a 198ft tall cylindrical structure (Weise 2016, 75). Whilst the footprint of these buildings is very small in the context of the overall area of the Archaeological Zone, their visual impact has been heavily criticised by Burmese heritage professionals (San Nan Shwe & Maung Hlaing 2015) and international experts (Messeri 2007, 3). In the context of inscription on the World Heritage List such concerns are particularly relevant given that threats to the setting of heritage sites is recognised by UNESCO as grounds for de-listing (Barbato & Turner 2015, 3). Whilst concerning, these cases are not representative of the character of urban development in the Archaeological Zone overall.

The zoning regulations are designed to limit the extent and impact of urban development and expansion within the overall Archaeological Zone of Bagan. However, despite the concerns around individual buildings, the effectiveness of the zoning regime has never been evaluated at the macro-level. This paper aims to undertake just such an evaluation in order to inform the heritage management of the area as a *landscape*, not simply a collection of important sites constructed on an otherwise neutral background. Fundamentally, it is a landscape in which people live and undertake religious pilgrimage to visit, not an enormous archaeological site to be preserved unchanged. As such, urban development for local inhabitants and the increasing pressure for economic improvements through tourism (MoHT 2013, 31) will continue to be balanced against the conservation priorities of international cultural bodies.

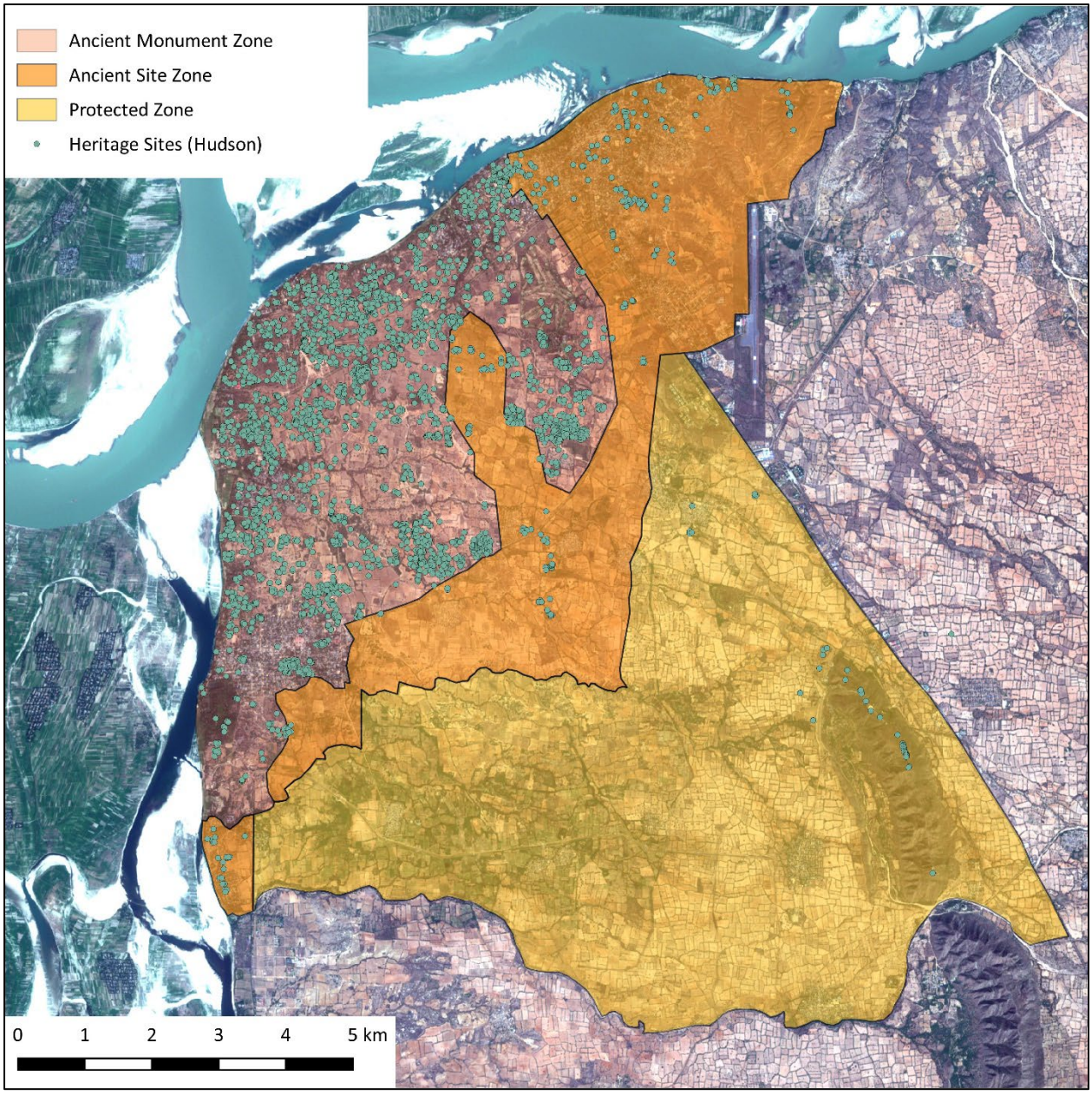

Figure 3: The heritage protection zones at Bagan and location of monuments (underlying image: Copernicus Sentinel data 2018)

3. Methods: Satellite-Remote Sensing and Land Cover Classification

The necessity of evaluating the *overall* effectiveness of the zoning regime required a method that could accurately measure changes in the area of urban development across the entire region, rather than concentrating on individual or anecdotal examples as proxies for actual data. Satellite data, providing wide-area coverage was the obvious choice, but its analysis required a choice of method. The analysis of satellite data beyond the simple identification of new archaeological sites, to establish changes in land-use, is now a well-established technique in fields as diverse as forestry, agronomy and, of course, heritage management (Parcak 2009); there are also a variety of approaches for analysing satellite

coverages, the choice of which appears to depend upon a compromise between speed and accuracy. 'Supervised Automatic Classification' is the current favoured method, where a user identifies land-use types, such as urban, forestry, farmland etc, to 'train' an algorithm, which then identifies such land-use types across the desired satellite image. Usually undertaken through a geographical information systems (GIS) interface, these land-use classes are automatically provided with accurate spatial information, congruent with the geographic projection used by the satellite imagery.

In heritage management this method has been used successfully, usually to monitor threats to heritage sites through land-use change, agricultural intensification or alterations to drainage or forest cover. Central Indian painted rock shelter sites falling prey to agricultural change were analysed using exactly this method, and the authors noted that accuracy after ground-truthing was 83.3% (Banerjee & Srivastava 2013, 197). Urban-sprawl in this context has also been the subject of analysis, with the technique particularly suited to the analysis of very large areas, such as the Paphos region of Cyprus, where a maximum accuracy of 95% was observed (Agapiou *et al.* 2015).

However, after testing a variety of supervised classification algorithms, this study on Bagan chose to eschew automatic methods, and rely on the visual classification of land-use by a human observer. There were a number of reasons for this choice. The only land-use type to be classified was urban, or semi-urban development (see below for the definition used in this study), in order to measure change of settlement size over time. There was therefore no need for an algorithm to determine other forms of land-use. Moreover, the area of Bagan, and the number of settlements it contains, is small enough that the time required to train the algorithm exceeded the time taken by a human observer to identify urban areas and label them manually. Initial attempts to train the automatic classification also highlighted problems in the algorithm's ability to separate the very low-density settlement and housing type in the Bagan area from areas of scrub wasteland, with the effect that urban areas were over-identified in the data. The time taken to correct this problem was the principle reason why manual classification was deemed more efficient.

4. Methods: Sources of Data and Processing

A variety of satellite-derived data sources are now available but few are entirely free to access, of global coverage, and available from a considerable span of time. However, Landsat 5 data provided freely by the USGS, and Sentinel 2 data provided freely through the EU Copernicus programme, fulfil all these requirements. Both of these satellite programmes provide detailed photographic coverage of the entire earth's surface. The time span chosen to examine land-use change was from the opening of the Bagan Symposium in 1988 (or the closest possible date from which a satellite picture without obscuring cloud was available), through to early 2018. Data was obtained in broadly 5-yearly intervals for this period, again dependent on availability without obscuring cloud; table 2 summarises the satellite platform and the date of acquisition. It should be noted that Sentinel 2 data, when it became available, was identified as preferable to Landsat images because of its higher resolution imagery: 10 metres per pixel compared to Landsat 5's 30 meters (ESA 2015, 51), allowing a more detailed view of urban areas. The absolute geometric uncertainty of these instruments is 30m for Landsat and 20m for Sentinel 2; however, because absolute geolocation is unnecessary for this analysis, the resolution values are the more relevant.

Platform	Date of Acquisition	Citation
Landsat 5	28.12.1987	Data available from the U.S. Geological Survey
	24.01.1992	
	05.01.1997	
	22.11.2003	
	18.02.2007	
	28.12.2011	
Sentinel 2a	23.12.2015	Copernicus Sentinel data 2015
Sentinel 2b	25.02.2018	Copernicus Sentinel data 2018

Table 2: Satellite data sources used in the study

The satellite coverages were imported in QGIS and full colour images produced from merging the visible light bands. This is a necessary step, as both satellite platforms record images in a number of different light spectra, from the visible to the near infrared. In order to create a 'correctly' coloured image, the red, green and blue bands must be combined together. For Landsat 5 RGB = bands 3, 2 and 1, respectively; for Sentinel 2 RGB = bands 4, 3 and 2, respectively. Shapefiles were produced for the three archaeological zones, discussed above; for the urban areas per satellite image (including the control area of Pakokku outside the Bagan region); and for the sites listed in Hudson's 'Bagan working database' (Hudson 2008b). All statistical information, discussed below, is derived from the analysis of these shapefiles.

5. Results of the Satellite Data Analysis

5.1 Definitions

Two important variables must be defined prior to any discussion of data analysis. The first of these is the nature of a 'monument' at Bagan. The data on monuments and their location is taken from the Bagan working database (Hudson 2008b). A 'monument' under this definition can be a temple, stupa, monastery, statue, ordination hall, inscription hall, image house or mound. No assumption is necessarily made concerning the date of construction, and it should be noted that the majority of entries in the database are temples, stupas or monasteries.

Second, the nature of an 'urban area' requires definition. The urban areas mapped from the satellite data were defined and identified as a series of residential and other buildings grouped together in a settlement. This deliberately excluded individual structures or isolated groups of farm buildings. No particular assumptions were made about size of the settlement, nor were there any preconditions about the density of settlement or the size of the structures within it. When mapping the edges of settlements, their limits were defined by the end of contiguous development: settlements therefore represent the spatially uninterrupted presence of buildings. In practice, the major factor in delineating this definition was practical: the 30m ground-resolution of the Landsat data *de facto* prevented the identification of any group of buildings of lesser extent, and in reality, the size of the settlement was usually substantially larger.

5.2 Baseline Data

The baseline data for the monuments within the Bagan Archaeological Zone directly reflects the design of the three different heritage zones defined in the Township Law. Using the [count points in polygon] function provided in the QGIS algorithms, the Ancient Monument Zone (the area of strictest development control) contains 3077 of the monuments listed in Hudson's database; the Ancient Site Zone contains 270 monuments; and Preserved and Protected Zone 38 monuments. Having identified the urban areas in all of these zones (see below), we can further identify that 521 monuments fall within areas of settlement as of February 2018. The area of the three land use zones is as follows:

Ancient Monument Zone:	32.6 square kilometres
Ancient Site Zone:	29.8 square kilometres
Protected and Preserved Zone:	59.6 square kilometres

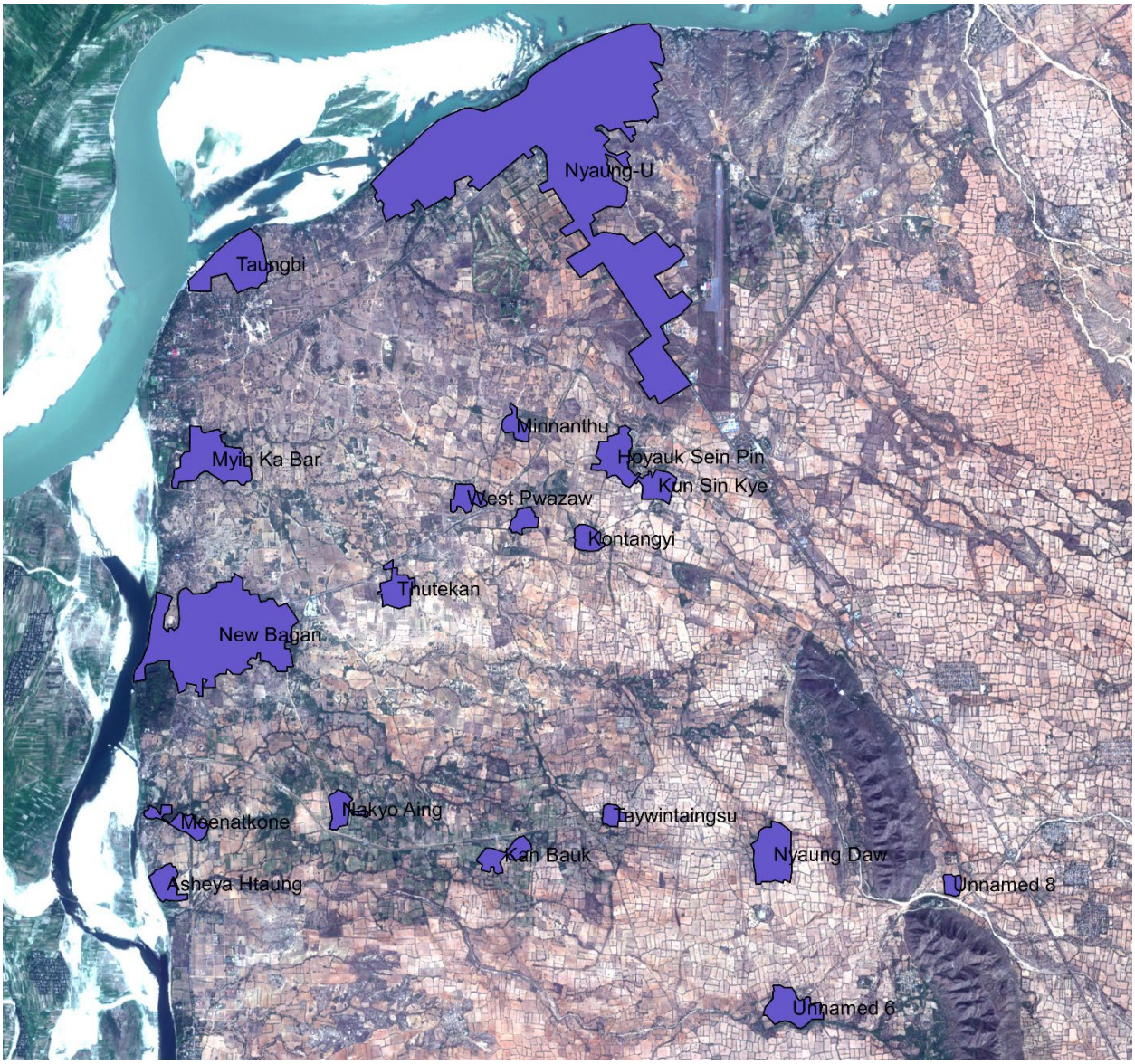

Figure 4: Urban areas as of 25.02.2018 (underlying image: Copernicus Sentinel data 2018)

5.3 Changes in Urban Area 1987 – 2018

The urban areas on each satellite image were manually traced and saved within a Shapefile – one for each image, each settlement was assigned a separate polygon within each Shapefile (see figure 4 for 2018 settlements). The names of settlements were recovered from a variety of sources: maps provided in technical documents and reports (JICA 2014; MoHT 2013; Crabolu 2015), and Google Earth. However, in two cases a settlement name could not be identified from available sources. Using the [autofields] plugin for QGIS[2] the area in square kilometres for each settlement within the Bagan Archaeological Zone was calculated. Table 3 and figure 5 display the change in urban coverage over the time period of the study.

Year	Area (sq. km)	% Change
1987	6.16	-
1992	5.51	-10.49
1997	9.02	63.60
2003	11.61	28.72
2007	12.92	11.32
2011	13.87	7.32
2015	14.42	3.98
2018	14.43	0.05

Table 3: Urban area by year

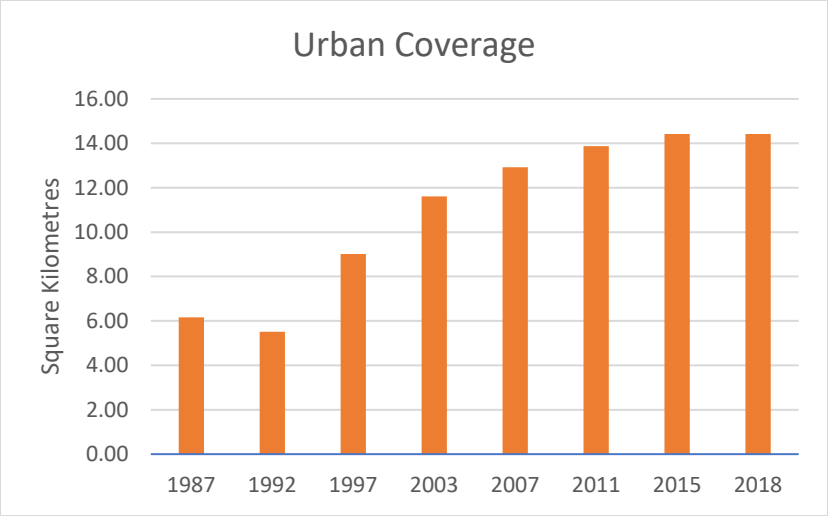

Figure 5: Urban coverage by year

It is clear from this data that there was a slight contraction in urban coverage between 1987 and 1992, then a steady but gradually decreasing rate of expansion over the subsequent years of the study. These rates of change can also be graphically expressed. Figure 6 displays this rate of change based on percentage increase from the previous data point.

[2] https://github.com/gacarrillor/AutoFields

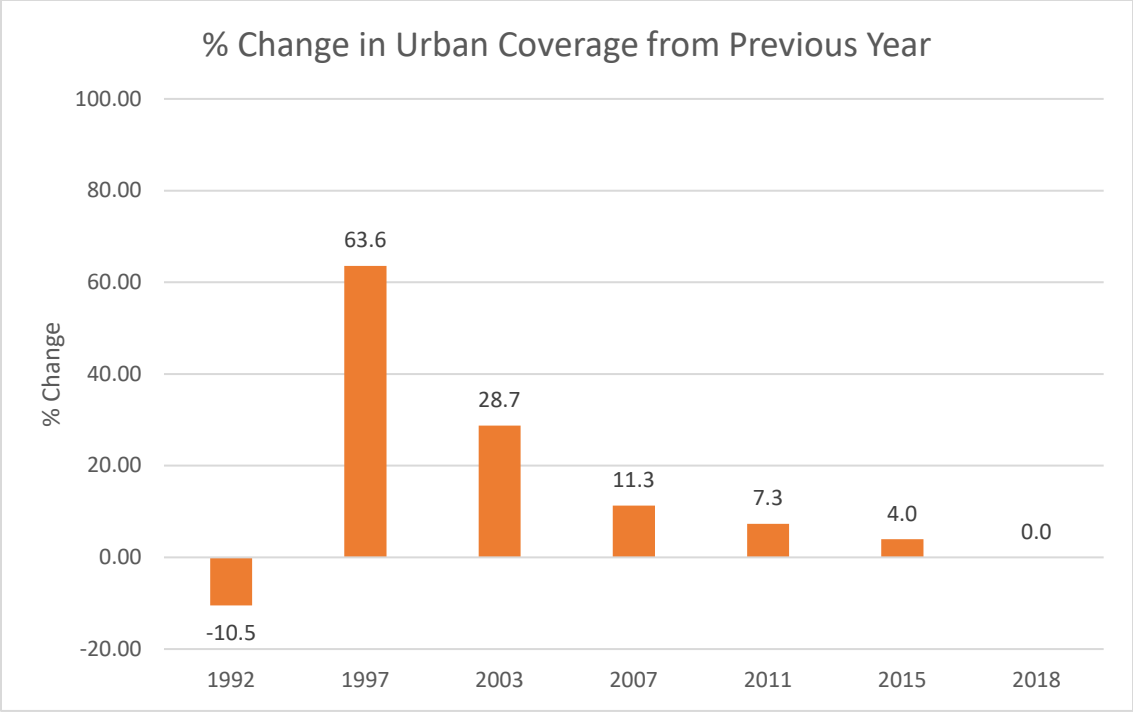

Figure 6: The rate of urban expansion

It is also instructive to consider the alteration in the size of two key settlements: Nyaung-U, the main services and accommodation hub for the area, as well as the location of the regional airport and railway station; and New Bagan, the settlement established in 1990 after the relocation of the inhabitants of Old Bagan (figure 7).

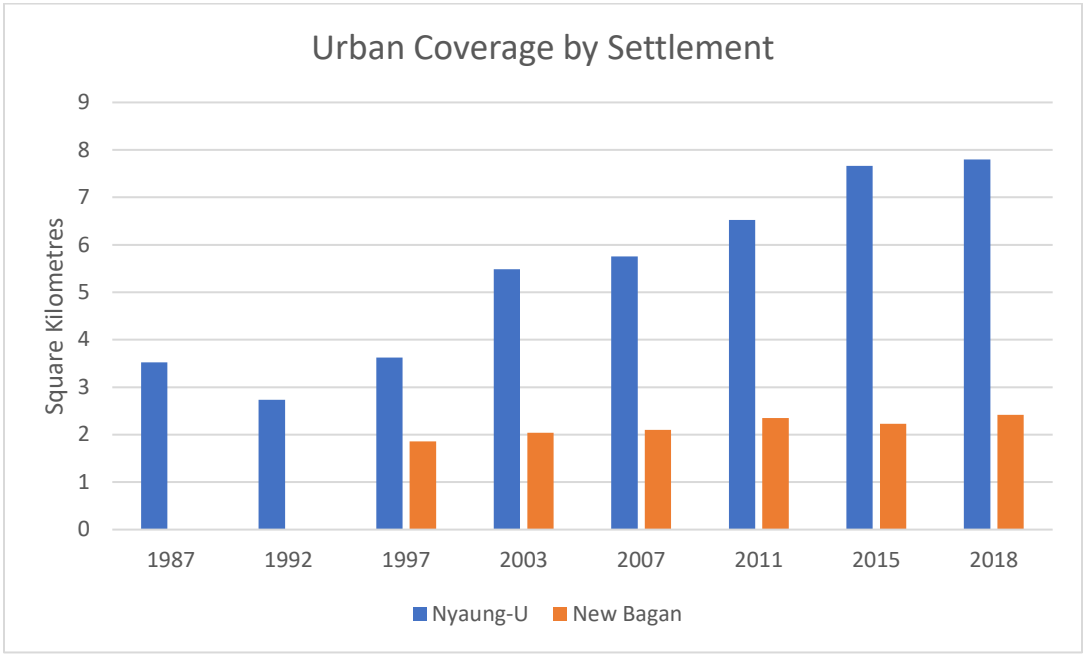

Figure 7: The size of Nyaung-U and New Bagan by year

It is interesting that, despite being founded in 1990, New Bagan is almost invisible on the satellite images from 1992 (see discussion and figure 9). The settlement almost achieves its maximum size between 1992 and 1997 and changes very little thereafter. Nyaung-U, in contrast follows the general trend of the region's urban areas (figure 8), with early contraction and then steady but slow expansion. This is particularly significant because, whilst Nyaung-U lies within the Ancient Site Zone, it has been the focus for permissive development to allow the creation of tourist infrastructure, paired with a designated 'hotel zone' to the east of the airport.

Whilst these data are instructive, they require comparison with the changes to urban areas *outside* the controlled planning environment of the three archaeological zones of Bagan. This allows the assessment as to whether the Bagan area was affected by its zoning, or whether it was merely reproducing wider trends in urban development. For this purpose, the settlements of Pakokku and Chauk were chosen as controls lying, respectfully, 30km to the north-east of Old Bagan on the opposite, northern, side of the Irrawaddy river; and 31km to the south. Pakokku and Chauk are useful comparators because as local settlements they are subject to similar regional constraints/opportunities for development, such as transport links, infrastructure, and the presence of the Irrawaddy. Pakokku has also been directly connected to the Bagan area by the Pakokku Bridge since it was opened in 2012, whilst Chauk has road and ferry links. Figure 8 compares the changes in urban area of Nyaung-U and New Bagan (both within the controlled zone), with the urban development of Pakokku and Chauk. See section 6 for a more detailed appreciation of the economy and development of these settlements.

Year	Pakokku Area (sq km)	Chauk Area (sq km)
1987	8.65	5.19
1992	8.70	5.52
1997	10.69	5.74
2003	11.01	6.29
2007	11.63	6.44
2011	16.05	6.83
2015	23.36	8.50
2018	24.46	9.24

Table 4: Urban area, and rate of change for control settlements (averaged)

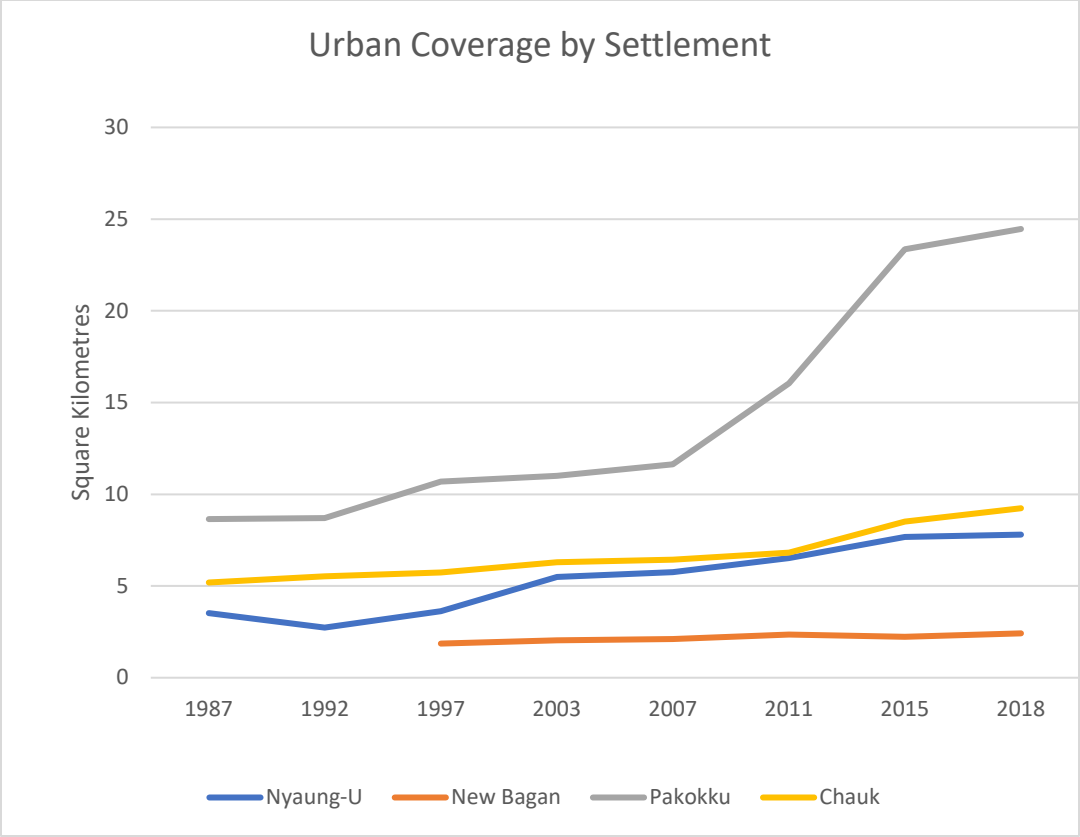

Figure 8: The development of the control settlements compared with major settlements in the Bagan area

The control settlement of Pakokku displays a stark contrast from the areas within the Bagan Archaeological Zone. Whilst it appears that the rate of development broadly paralleled the Bagan area until 2007, thereafter the rate of change increased rapidly, whilst settlement change within the Archaeological Zone remained stable. Chauk, on the other hand, maintains slow and steady growth until 2011, at which point the rate increases slightly. The significant observation here, is that Chauk outstrips the growth rate of Nyaung-U from 2011 onwards, despite the advantages enjoyed by Nyaung-U in the form of tourist inflow to Bagan and the presence of a developing airport. Thus, both control settlements experience higher rates of growth than settlements within the archaeological zones of Bagan. The reasons for these trends and potential explanations are explored in the next section.

6. Discussion: Urban Development in its Context

The trend in urban expansion within the Bagan Archaeological Zone is upward but relatively steady, with a levelling-off in recent years. The contraction evident between 1987 and 1992 corresponds with Burmese economic problems following the collapse of the Ne Win government and the declaration of martial law in 1988. Similarly, the rapid expansion between 1992 and 1997 is largely explicable by the formation of New Bagan, leading to a sudden jump in urban area, and perhaps the relaxation of visa restrictions to encourage tourism in 'Visit Myanmar Year' in 1996. However, the invisibility of New Bagan on the satellite imagery from 1992 is unusual, given that New Bagan was officially created in 1990. Directly comparing the satellite imagery (figure 9) indicates that the settlement appears to have

developed very slowly. The area set aside for settlement is clear, with a road or track grid system evident, but there is a lack of visible permanent structures even two years after the settlement was formally established. This observation certainly reinforces the ethical criticism of the forced relocation of people to New Bagan, discussed above. In the context of the effectiveness of the heritage zoning regime, it is noteworthy that New Bagan has increased in size very slowly following its establishment (figure 7), and thus development appears to have been controlled.

Figure 9: The area of New Bagan (centre) in 1987, 1992 and 1997, respectively

Nyaung-U on the other hand does see somewhat greater development than other settlements within the Archaeological Zone, although still comparable to the overall trend of slow expansion. This appears to be due to its status as the local transport and economy hub, and the accepted level of development allowed for hotels and service industries in this area. Relevant here is the observation that urban expansion remained stable despite the economic liberalisation of 2011 under the new government, and in this context the evidence for the effectiveness of the zoning regime becomes most striking.

Between 2007 and 2015 the control settlements of Pakokku and Chauk, outside the Archaeological Zone, grew more rapidly *in contrast* to the area of Bagan. This development increased in speed from 2011, corresponding with liberalisation but also, in the case of Pakokku, with the opening of the Pakokku Bridge over the Irrawaddy in 2012: an infrastructure project that appears to have had economic benefits. However, this development was underway before liberalisation from 2007, and the rate of change began outstripping the Bagan area from this time. If both Pakokku and Chauk demonstrate growth, we must examine the very sharp increase in size of Pakokku. Pakokku is the site of an industrial zone, one of 19 established from the mid-1990s by the State Law and Order Council, and whilst these zones are not efficiently managed or adequately resourced (Robertson & Seng Taung 2015, 7), it appears this may be a factor driving economic growth. Economic liberalisation in 2011 also corresponded with a shift away from inefficient state-supported industries in the Pakokku Industrial Zone, with the closure of uneconomic motorcycle manufacturing (Kudo & Kumagai 2019, 141), a factor that may also have encouraged growth.

Chauk, in contrast, is almost entirely reliant on low-intensity agriculture for economic support: an insecure economic foundation in the 'dry zone' of central Myanmar. The Chauk region suffers from increasing pressure from soil degradation, which tripled in intensity between 2000 and 2015 (Tun *et al.* 2015, 10), and from trends in rural depopulation towards the major regional cities (Belton & Filipski 2019). Indeed, data indicates that a diversification of livelihood is becoming a household strategy to ensure food security in the dry zone, with family members increasingly been drawn to the service sector

(Pritchard *et al.* 2019, 89). Chauk is therefore a particularly interesting case as, remarkably, *despite* negative pressures on agriculture and rural depopulation in central Myanmar, Chauk *still grew more quickly* than settlements at Bagan, even though Bagan appears the perfect destination for people arriving to work in the service sector as a means of diversifying rural income.

Thus, it appears that at the macro-scale at least, heritage zoning in the Bagan Archaeological Zone *has* been an effective tool for managing urban expansion. Pakokku and Chauk expand but the settlements in the Bagan area do not. This is despite the fact that Bagan has the particular economic asset of a huge number of Buddhist remains and their foci as a destination for pilgrimage. It is reasonable to assume that the Bagan area settlements, particularly New Bagan and Nyaung-U as the site of most local hotels, would have seen similar or greater levels of expansion if growth had remained uncontrolled. We may envision a situation where, without any zoning controls, somewhere between Pakokku/Chauk levels could have been taken as a baseline for expansion, with additional development over and above this level due to the presence of the religious monuments in the area and the ease of local access to national transport links.

6.1 Non-Architectural Expansion of Urban Areas

A final issue, and one that is certainly macro in scale, is the sprawl of the non-structural or unbuilt elements of urban areas. In the context of the Bagan region this is typified by the dumping of waste in the areas immediately adjoining settlements (figure 10). Around settlements that are completely surrounded by heritage zoning, such as New Bagan or Myin K Bar, the large-scale accumulation of domestic waste and litter means that *in effect* these urban areas are in fact encroaching beyond their zoned limits. A quantified study of this effect is beyond the scope of this paper, but waste accumulation outside of settlements within all heritage zones was observed during the authors' latest field visit, to the extent that it can be considered endemic and widespread. Of particular concern was the amount of non-biodegradable, mainly plastic waste. Whilst this is obviously of environmental concern, it has the potential to adversely affect the setting of important monuments in a similar manner to the criticisms already observed for the Archaeological Museum and the Nan Myint viewing tower – it may be a very different effect, but it is certainly negative. Indeed, in the context of the ongoing management of Bagan as a World Heritage Site, it should be noted that litter has been listed as a threat to world heritage (UNESCO

Figure 10: Organic and inorganic waste as urban 'sprawl' near New Bagan

2016, 68). It is also a threat that is likely to increase in scale and severity, albeit from different sources, as tourism increases in the area, now that WHS status has been gained (du Cros 2007, 236; Timothy & Boyd 2003, 118). There is every possibility that higher resolution satellite imagery may allow us to quantify this extra-settlement effect in future research.

7. Conclusions

The delineation of the Bagan Archaeological Zone into three hierarchical areas of land-use control appears to have worked to limit urban sprawl in the area, and thereby to limit the damage from development to the monuments and also crucially, to their setting. As a response to UNESCO concerns about the effectiveness of zoning as method of control, it appears that the three zones have functioned correctly. However, there are certain caveats to apply. This analysis has been undertaken at the macro-scale, and it measures overall settlement area growth without reflecting on individual transgressions that may have a greater impact on the setting of monuments than urban expansion generally, such as the construction of the Bagan Archaeological Museum and the Nan Myint viewing tower. We may therefore argue that the heritage zones effectively control local, small-scale development, but have limits where large capital construction projects are concerned. Furthermore, as a macro-scale analysis, these results do not reflect upon damage to individual monuments due to poor quality reconstruction, or particular instances of urban construction or development that may have broken the rules – this data is not available when working at this scale. Overall the heritage zoning system appears to have functioned well when compared with the expansion of other local settlements, and this should be taken as a strong argument for its more rigorous enforcement for all scales of construction project that may have an impact on monuments directly, or upon their setting.

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