

A Bayesian approach to dating agricultural terraces: a case from the Philippines

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Field terraces are notoriously difficult to date – but historically of high significance. Here the author uses a Bayesian model applied to radiocarbon dates to date the tiered rice fields of the northern Philippines. They turn out to have been built in the sixteenth century probably by peoples retreating inland and upland from the Spanish.

Keywords: Philippines, Ifugao, sixteenth century, Spanish, rice, terraced fields

Introduction

Practices of relative dating techniques in archaeology have been modified by newer and more easily accessible radiometric dating methods (i.e. AMS, TL, etc.) and the realisation that some archaeological strata are not formed by straightforward top-to-bottom, younger-to-older relationships. The diminishing reliance on 'stratigraphic superposition' in archaeological reconstruction and greater emphasis on radiometric dating (especially ^{14}C dating), have created a pitfall for arbitrary interpretation of the calibrated information provided by laboratory results, which might not relate to the archaeological event being dated.

Following Dye's (in press) call for a standard methodology for calibrating ^{14}C results and incorporation of stratigraphic information in the calibration, this article proposes the use of Bayesian modelling (Buck *et al.* 1996) to date agricultural terraces, which by nature have layers with a chaotic mixture of materials. I use the Ifugao rice terraces of the northern Philippines as a case study to illustrate the suitability of Bayesian calibration and modelling in establishing archaeological chronology. Anywhere in the world, dating agricultural terraces presents methodological difficulties because of their construction technology and use. However, as this article illustrates, a Bayesian approach addresses the problem by incorporating stratigraphy, ethnographic information and ^{14}C dates in the calibration process.

In addition, the Ifugao case study offers a significant contribution to anthropological studies of agricultural intensification. Foremost of these is the illumination of relationships between landscape, water management and social organisation. However, to understand these relationships in a diachronic perspective, it is necessary to determine when the Ifugao constructed the earliest rice terraces.

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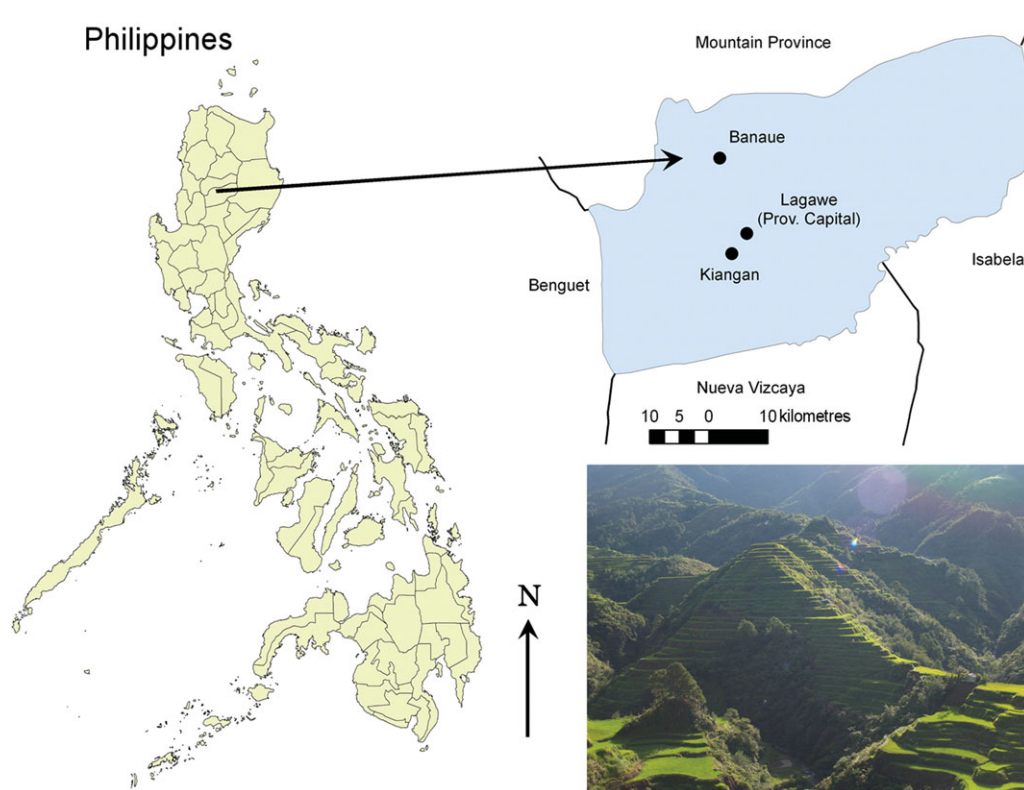


Figure 1. Ifugao province with the location of the municipalities of Banaue and Kiangán, Ifugao (inset: Hanga and Talugtug terraces in Viewpoint, Banaue, Ifugao).

The Ifugao rice terraces

The origins and age of the Ifugao rice terraces in the Philippine Cordillera (Figure 1) continue to provoke interest and imagination in academic and popular debates (Table 1). For Southeast Asian scholars, dating these terraces is critical for understanding Philippine prehistory and Southeast Asian patterns more generally. Beyond the scholarly community, the terraced Ifugao landscape has captured the world's imagination as an important cultural landscape (UNESCO 1995). To date however, insufficient work has been undertaken to determine either when the terraces were first constructed, or the period of time involved in building this tiered landscape.

The Ifugao are one of several minority ethnolinguistic groups in the northern Philippines, and one of the best documented by ethnohistoric and anthropological scholars. At the turn of the twentieth century two prominent figures in Philippine anthropology began an intensive investigation of the Ifugao (Barton 1919, 1930; Beyer 1926, 1955). Both scholars proposed a 2000-3000 year old origin for the Ifugao rice terraces, using observations and qualitative speculations on how long it would have taken the Ifugao to modify the rugged topography of the area (Figure 1). This 'long history' has become a kind of received wisdom that finds its way into textbooks and national histories (UNESCO 1995; Jocano 2001).

Table 1. Age-estimations proposed for the inception of the Ifugao rice terraces.

Author	Date	Evidence
Barton (1919) & Beyer (1955)	2000-3000 YBP	Estimated how long it would have taken to construct the elaborate terrace systems which fill valley after valley of Ifugao country.
Keesing (1962) & Dozier (1966)	<300 YBP	Movements to upper elevation of Cordillera peoples were associated with the Spanish pressure.
Lambrecht (1967)	<300 YBP	Used lexical and linguistic evidence by analysing Ifugao romantic tales (<i>budhud</i>); observed short duration of terrace building and concluded a recent origin of the terraces.
Maher (1973: 52-5)	205 ± 100 YBP 735 ± 105 YBP	Radiocarbon dates from a pond field and midden (refer to Table 2)

At the other end of the spectrum, several scholars have proposed a more recent origin of the Ifugao rice terraces. Using evidence from lexical information and ethnohistoric documents, these studies suggest that the terraced landscapes of the Ifugao are the end-result of population expansion into the Cordillera highlands in response to Spanish colonisation. Lowland-mountain contacts are known even before the Spanish arrival. These contacts might have facilitated the movement of lowland peoples to the highlands when the Spanish established bases in their locales (Keesing 1962).

Today, the Ifugao practise a combination of wet-rice terraced farming and swiddening. This agricultural system is significant in the traditional organisation of their society. The elite (*kadangyan*) own the wet-terraced rice fields, while the swidden fields are cultivated by the lowest social class (*nawatwat*) (Brosius 1988). Eder (1982) pointed out that the imposition of the colonial-period state system degraded the relationship between the *kadangyan* and the *nawatwat*. Previously, the *kadangyan* possessed enormous social influence in Ifugao society: they decided on the programmes for terrace-building, maintenance, and rituals. With the assimilation of the Ifugao by wider lowland Philippine society, this social dynamic has since changed. It also has profound implications in the maintenance and conservation of these structures.

Resolving the antiquity of the entire Cordillera terraced field tradition requires archaeological work to determine whether the conventional 'long history' or the revisionist 'short history' more accurately represents the occupational history of this region. Such work requires decades of research in different provinces across the mountainous region, beginning with areas within Ifugao province.

Ethnohistoric and previous archaeological research

The Spanish discovered the Philippine islands in AD 1521. However, permanent presence and establishment of colonial control did not begin until AD 1565. They began their

Table 2. ^{14}C determinations collected by Maher (1973).

Site	^{14}C age	Material	Calibrated dates (Cal AD, 2σ – 95%)	Descriptions
If1	205 ± 100 BP	Charcoal (Runo reed)	AD 1470-1879	Sample taken from a pond-field
If2 55E85	325 ± 110 BP	Charcoal (no description presented)	AD 1401-1808	Sample taken from house platform
If2 85E90	695 ± 100 BP	Charcoal (no description presented)	AD 1157-1428	Sample taken from midden on slope
If2 85E95	735 ± 105 BP	Charcoal (no description presented)	AD 1039-1406	Sample taken from midden on slope
If3	2950 ± 250 BP	Charcoal (no description presented)	1409-916 BC	Sample was taken from a house platform; no depth or layer description included in published article; early date might not represent terracing.

expeditions on the western side of northern Luzon (Ilocos provinces) in AD 1572 and established garrisons in the Cagayan Valley in AD 1591 (Keesing 1962: 20-5). They did not establish a permanent presence in Ifugao until AD 1793, when they occupied the town of Kiangnan.

The earliest ethnohistoric record for Ifugao rice terraces comes from an AD 1801 letter of Fray Juan Molano, OP (Scott 1974: 199). The dearth of references to this terracing system in colonial Spanish accounts from AD 1572 to AD 1750 led Keesing (1962: 319) to conclude that Ifugao rice terracing was of comparatively recent innovation. The irrigated, terraced fields were already known to the Spanish during the first expeditions to Kiangnan (c. 30km south of Banaue) in the 1750s, but formal description did not come until the successful Spanish occupation of the town in AD 1793. The valley of Banaue, however, was not discovered by Europeans until 1868 (Scott 1974: 238). In my working model, terrace construction must predate AD 1793.

The only prior archaeological information on this region derives from one set of radiocarbon dates from an Ifugao locality that Maher (1973) published, based on his work in the Banaue district. He published five ^{14}C determinations (Table 2) the earliest of which could suggest terrace construction by 2950 BP: this is well over a millennium before Spanish arrival and colonisation. As discussed below, however, Maher's analysis and interpretation do not confirm the pre-Hispanic origins of these indigenous agricultural structures. These dates are significant in determining the presence of populations in the area but not necessarily the existence of rice terraces.

Two issues weaken Maher's radiocarbon estimations: their depositional context and in-built age. Almost all of his charcoal samples did not come directly from rice terraces, and the one that does (If1 in Table 2), is most likely to represent use rather than construction. In-built age is another issue. The 'old wood' problem has not been identified during the period of his study, but we now know that the failure to address this issue can bias '*archaeological chronologies toward an excessive antiquity*' (Schiffer 1986: 19; Taylor 1987). Even an in-built age of a couple of hundred years would make it difficult to test the hypothesis of a Spanish

impetus for terrace construction (a calendar date of AD 1401 might actually be a Spanish period event).

Moreover, establishing the dates of terrace construction in Ifugao provides a broader ramification in the anthropological study of agricultural systems. The development of Ifugao rice terraces might prove that the large agricultural terrace construction does not always proceed in a slow, incremental expansion. As Ladefoged and Graves (2008) alluded in their study of the Kohala field system in Hawai'i, rapid expansion (or intensification of production) in marginal areas might be a manifestation of elite desire for generating surpluses.

Bayesian approach

A conventional ^{14}C age determines when the dated sample was alive and growing within an animal or plant. However accurate this date, it does not necessarily relate to the age of the archaeological event to be dated because the sample may have originated in a different, though stratigraphically related, context (Dye in press: 108-10). An example of this type of event in Ifugao is the construction of stone walls where river boulders are used as terrace-wall foundations, but plant and animal parts are not used. An archaeologist hoping to estimate the age of the structure might recover material older than the structure from the sediment beneath it, or, less commonly, material younger than the structure from sediment that buried it, but there is no material suitable for ^{14}C dating that is directly associated with the construction event. In situations such as these, the archaeologist may use a Bayesian calibration procedure that anchors the event within a sequence of radiocarbon dates that are pre-ordered by additional data.

The ability of Bayesian calibration to reconcile chronological information of different types provides a powerful approach (Buck *et al.* 1996). In Ifugao terrace construction technique some layers are made up of earth fill dug out from elsewhere and therefore containing material of various dates (Figure 2). The Bayesian approach starts with what is known about the relative deposition order of the two layers and then modifies this knowledge in the light of the ^{14}C dating information. Samples reported here were taken from the layer under the terrace wall and the layer where the terrace wall is located. Since the layer under the terrace wall is untouched (according to Ifugao terrace construction technology), it is safe to assume that the bottom layer is older than the one above it. Using the BCal calibrating software package (Buck *et al.* 1999), the samples yield calibrated ages that agree with their stratigraphic positions (see section on the Interpretation of Chronometric Results). There is no longer a need to resort to *ad hoc* procedures to interpret the results in an archaeologically meaningful way. By taking into account the hard-won stratigraphic information collected in the field, the Bayesian calibration yields results that are immediately interpretable (Dye in press: 110).

Field investigations

I began studying the Ifugao landscape as part of an MA program that eventually led to a thesis on the distribution of rice terraces in Banaue, Ifugao (Acabado 2003). This MA thesis was

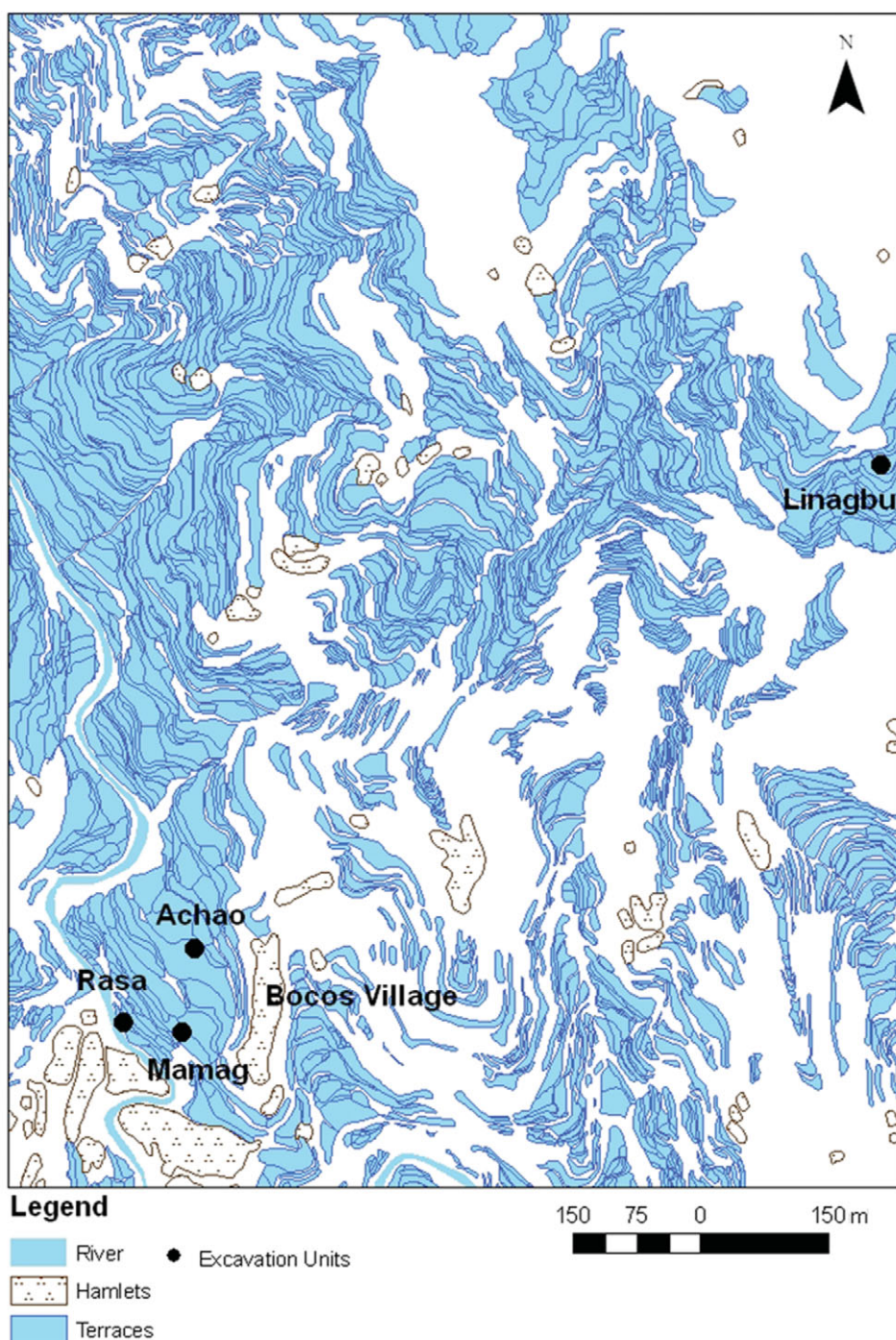


Figure 2. Location of excavation units in the Bocos terrace system. Rasa at 1040m asl; Mamag at 1060m asl; Achao at 1070m asl; and Linagbu at 1340m asl. Alimit River is the main source of water of Banaue terraces. Linagbu, which is located near the summit of the mountain gets water from an irrigation ditch whose source is a tributary of Alimit River, 3km away. Unit names used are based on local place names.

mainly based on Conklin's (1972) land use maps of North Central Cordillera, Philippines. Conklin's (1967, 1972, 1980) intensive studies of the Ifugao agricultural system provided baseline information on the distribution of rice terraces and swidden fields in the Banaue, Ifugao, landscape. His investigations produced the landmark land use maps (Conklin 1967) and the Ifugao Ethnographic Atlas (Conklin 1980). I digitized these land use maps using GIS software and used their data to select optimal locations for archaeological excavations (Figure 2).

Using the information gleaned from the digitized land use maps and ethnographic data on rice terracing practices in Ifugao, I identified four excavation units within the Bocos terrace system (Municipality of Banaue, Ifugao) to obtain charcoal samples for radiocarbon determinations. These excavation units were selected based on their proximity to the river, with the assumption that units nearest to the river would provide the earliest dates (Keesing 1962: 322; Maher 1973). Moreover, the Bocos system is located on the southernmost section of the Banaue terrace systems. Working on the assumption that populations were moving up the valley through Alimit River, then, Bocos terraces should be the oldest in the Banaue area. More importantly, the environmental features of Bocos suggest less energy requirement for terrace-building and more optimal for wet-rice production: less slope gradient, better water source and adjacent to a village.

During the summer of 2007, with the help of graduate students from the Archaeological Studies Program of the University of the Philippines and local Ifugao farmers, I excavated two units located near Alimit River, one excavation unit in the middle of the terrace system and one excavation unit on mountain top terraces. Following Conklin's (1980) cross-sectional illustration of an Ifugao pond-field (Figure 3) and information culled from local Ifugao farmers, I chose to excavate the wall section of the terraces. I believe that the wall foundation is the best location for dating the construction of a particular terrace. Ifugao farmers stated that even though some terrace walls occasionally collapse, wall foundations (*kopnad*) generally remain in their original place.

Two charcoal samples acquired from each excavation unit were used for ^{14}C dating. These were collected from the layer beneath the wall foundation and from the layer within which the wall foundation is located. All of the excavation units yielded similar stratigraphic profiles: Layer I, cultivated soil (*luyo*); Layer II, hard earth fill and wall foundation (*haguntal* and *gopnad*, respectively); and Layer III, original valley floor (*doplah*) (Figure 4). Three of the four excavation units provided data that corresponded with the Bayesian model for dating rice terrace construction used in this study (discussed below). The unit located in the middle of the system (Achao) produced a single charcoal sample from Layer II, thus, the information provided by unit Achao was used to support the use-date of the terrace. All of the charcoal samples were remains of *Pinus kesiya* Royle ex Gordon, commonly known as Cordillera pine, which has a lifespan of 100-150 years (Kha 1965: 25-6).

Chronometric data

The collected charcoal samples were submitted to the NSF-Arizona AMS Laboratory (Table 3). Dating at this laboratory was performed using a conventional stable isotope mass spectrometer to provide $\delta^{13}\text{C}$ measurements. Calibrations of the ^{14}C determination

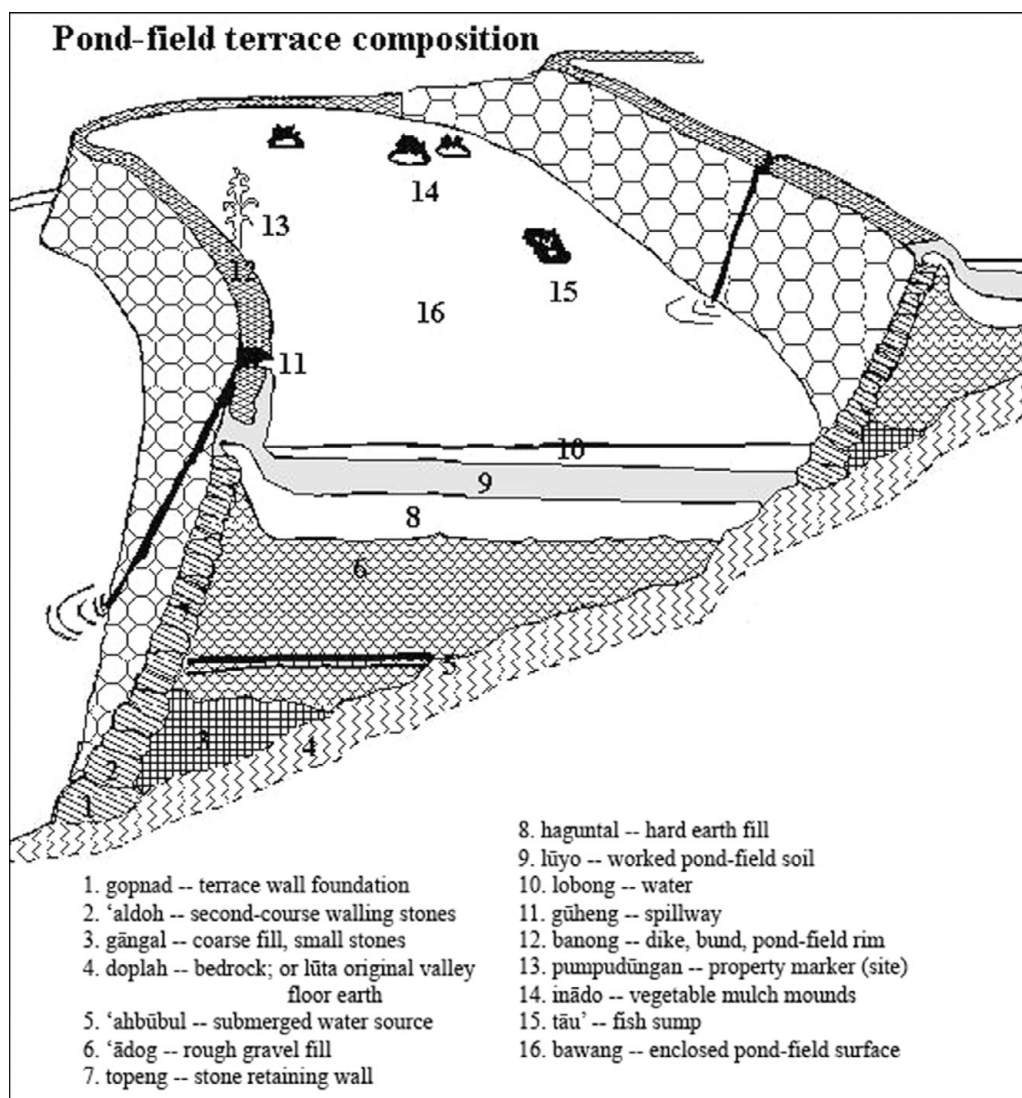


Figure 3. Cross-section of an Ifugao pond-field in a concave-slope valley with area sampled for excavation (adapted from Conklin 1980: 16).

results were done using the online program BCal. BCal is a Bayesian calibration program that provides the user a means to include archaeological, historical and stratigraphic information into the calibration procedure.

Seven ^{14}C dates on *Pinus kesiya* Royle ex Gordon charcoal (wood taxa identified by Dr Florence Soriano and the staff of Forest Products Research and Development Institute, University of the Philippines – Los Baños) from the Bocos rice terrace system (Table 3) provide the data needed to construct an absolute chronology for the stratigraphic and construction sequences of Banaue rice terraces. This dataset allows integration of relative stratigraphic information through a Bayesian statistical framework

Table 3. ^{14}C dates on *Pinus kesiya* charcoal obtained from the Bocos terrace system, Banaue, Ifugao.

Lab. no.	Unit	DBS [‡]	Dep. Unit (Layer)	CRA [*]	$\delta^{13}\text{C}$ ^{**}	Cal AD (BCal) ^{***}
AA78973	Mamag	0.85m	Layer II	119 ± 38	25.2	1687-1862
AA78974	Mamag	1.3m	Layer III	485 ± 39	-27.5	1325-1460
AA78971	Rasa	0.35m	Layer II	313 ± 38	-24.4	1620-1800
AA78972	Rasa	0.52m	Layer III	164 ± 38	-26.0	1527-1757
AA78969	Linagbu	0.55m	Layer II	180 ± 38	-26.5	1736-1867
AA78970	Linagbu	0.75m	Layer III	131 ± 38	-29.3	1663-1753
AA78975	Achao	0.75m	Layer II	193 ± 35	-25.0	1646-1809

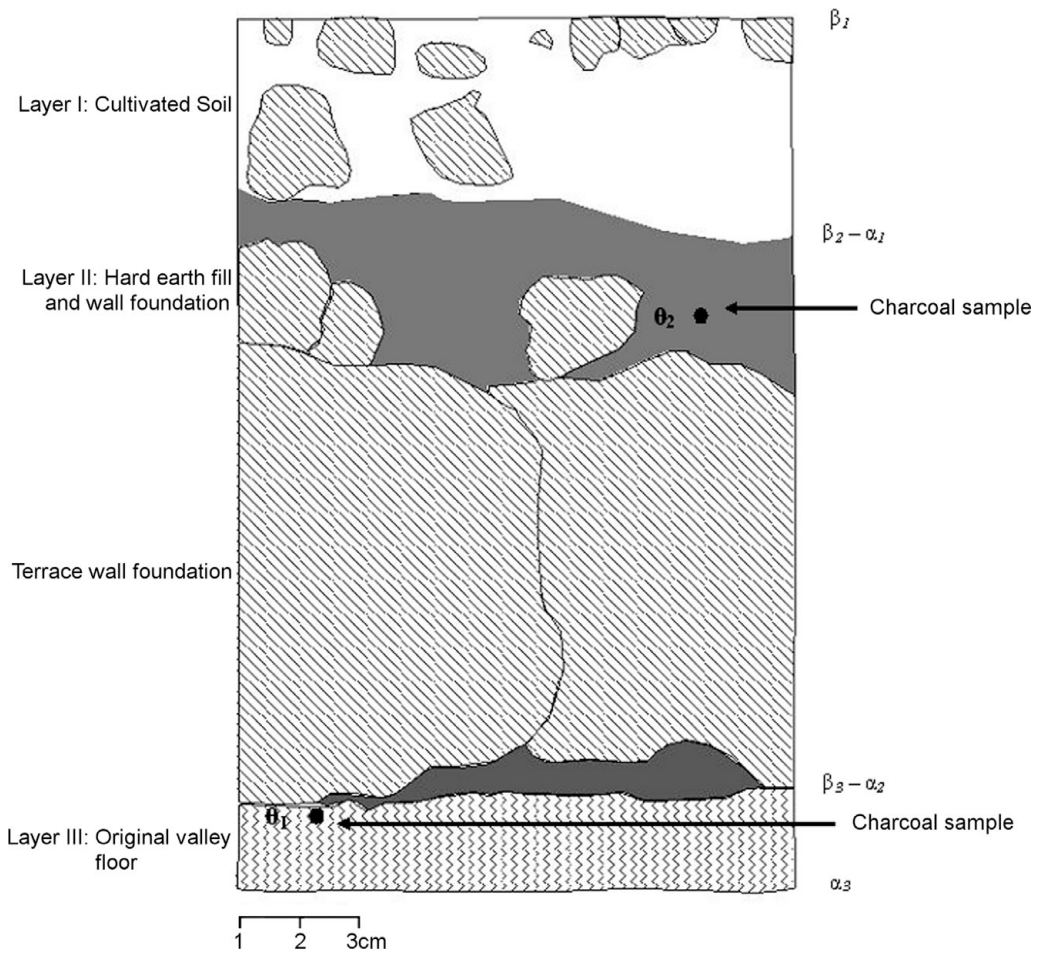
[‡]Depth below surface.^{*}Conventional radiocarbon age (Stuiver & Polach 1977).^{**}Parts per thousand, ‰.^{***}Calibration program BCal (<http://bcal.sheffield.ac.uk>, Buck *et al.* 1999).

Figure 4. Typical profile of excavation units and location of charcoal samples in the Bocos terrace system.

(Buck *et al.* 1991, 1992, 1996). This approach has the ability to include information on relative ages of dated events that can be used to constrain the calibrated ages of dated samples. Thus, we can assume that the calibrated age of a sample will always be younger than the calibrated age of a sample recovered from a stratigraphically older deposit, regardless of the relative ^{14}C ages of the two samples.

Linagbu and Rasa excavation units yielded inverted ^{14}C ages. However, due to their stratigraphic relationships, these samples were restored to their correct relative ages – the layer under the terrace wall is older than the layer above it (even with intermixing of materials). As a result, the addition of stratigraphic information to the calibration procedure improves the archaeological interpretability of the age-estimations. Guided by a Bayesian framework, we are provided with a means to obtain age estimates for events that were not directly dated, which is useful in this case because it is possible to estimate ages of depositional unit boundaries and as a result, the dating of wall construction. This stratigraphic relationship can be illustrated in the following simple equation:

$$E_3 > E_2 > E_1 \text{ (where } E_3: \text{Layer III; } E_2: \text{Layer II; } E_1: \text{Layer I)}$$

The single ^{14}C determination provided by excavation unit Achao offers information on the period of use of this terrace. The use-date of Achao agrees with the results of the Bayesian calibration of the other three units (Mamag, Rasa, and Linagbu): while riverine terraces (Mamag and Rasa) showed earlier dates and the mountain-top terrace (Linagbu) showed later dates, Achao presented an intermediate date.

The model

The primary objective of this ^{14}C calibration is to estimate the most probable period of terrace wall construction and use. However, classical calibrations of ^{14}C determinations only provide a date range of the life of the *Pinus*. Thus, it is useful to use Bayesian modelling to produce estimates of wall construction and subsequent use.

I put forward a model in which the construction of rice terrace walls in the Banaue Valley, B_w , is included as a statistical parameter in the calibration of radiocarbon dates obtained from the area. This model applies to the datasets provided by excavation units Mamag, Rasa and Linagbu. In this model, each layer corresponds to a period (the beginning of which will be represented by α variables and the end by β variables). Layer III, initial occupation of the valley, is represented by $\alpha_3 - \beta_3$, with θ_i as the ^{14}C determination; Layer 2, use-date of the terrace, is represented by $\alpha_2 - \beta_2$, with θ_{ii} as the ^{14}C determination; and Layer I, cultivated soil, is represented by $\alpha_1 - \beta_1$. Given the stratigraphic and ^{14}C information, it is possible to formulate a model of the relationships among depositional units and unknown calendar ages of events represented by two ^{14}C dates (for each unit).

This paper represents the initial Ifugao occupation of the area by α_3 and β_3 , with θ_i representing the ^{14}C determination. Since there is no *a priori* information relating to the calendar dates of the occupation, we assume the date of initial occupation lies between 2950 BP (earliest ^{14}C date from the valley of Banaue provided by Maher (1973)) and AD 1868 (Spanish discovery of the valley with significant populations (Scott 1974)). Therefore, archaeological and ^{14}C information from terrace stratigraphy can be expressed

Table 4. Probability analyses of pre-Spanish or post-Spanish construction of Bocos rice terrace walls.

Excavation unit	Elevation (metres above sea level)	Post-Spanish (Post-AD 1585) probability
Mamag	1040	74.6%
Rasa	1060	98.5%
Linagbu	1340	99.9%

in the following relationships:

$$\alpha_3 > \theta_i > \beta_3 > \alpha_2 \geq B_w > \theta_{ii} > \beta_2 > \alpha_1 > \beta_1$$

(This model was implemented using the BCal software package.)

Events in the Layer III deposit, exemplified by $\alpha_3 - \beta_3$, are likely to have occurred either very early in the colonisation period, or before the Ifugao arrival in the area. Thus, it is safe to assume that events in Layer III deposits pre-date significant Ifugao rice terrace construction activities (Layer II) at Banaue. Even if ^{14}C samples came from earth fillings, the Bayesian model takes into account that the layer is younger than the layer under the wall foundation.

Conclusion

Using this methodology it appears that terrace building in the valley of Banaue dates after AD 1585 (Figure 5; Table 4). The results of calibration and modelling of this study counter-indicate Beyer's and Barton's hypotheses while supporting Keesing's and Lambrecht's arguments. The Bayesian modelling employed in this investigation shows that the Bocos terrace system saw rapid terrace expansion between c. AD 1486 and AD 1788 – 302 years from the valley floor to the mountain top. Furthermore, there is also an indication of temporal change, as illustrated by the dates generated for terrace wall construction.

Whether this expansion reflects the elite (*kadangyan*) demand for surplus (rice-land holdings are one of the major determinants of Ifugao social ranking) or based on commoners' (*nawatwat*) exploitation of marginal environments to move up the social ladder, remains unclear. Despite the likely increase in population due to lowland groups escaping the Spanish, contact-period descriptions of Ifugao settlements point to low population densities. The startlingly high population density found in the twentieth century could be a later development, resulting in extension of terraces to steeper slopes and in higher step formations (Keesing 1962: 321-4). However, these movements could be the impetus for more terrace construction.

If the initial terrace expansion coincides with the arrival of the Spanish in the northern Luzon lowlands in AD 1585, this correlation may suggest that indigenous population migration away from the Spanish and into this highland *refugium* was significant enough to expand terrace systems. By the time the Europeans explored the eastern fringes of the Ifugao territory in the 1750s (Kiangnan and Lagawe locales), Ifugao populations had already established long-term settlements within Ifugao province. Antolin (1789) observed abandoned agricultural terraces in the Cagayan and Magat river valleys similar to the Ifugao terraces. This observation suggests that there were Ifugao or terracing populations in these

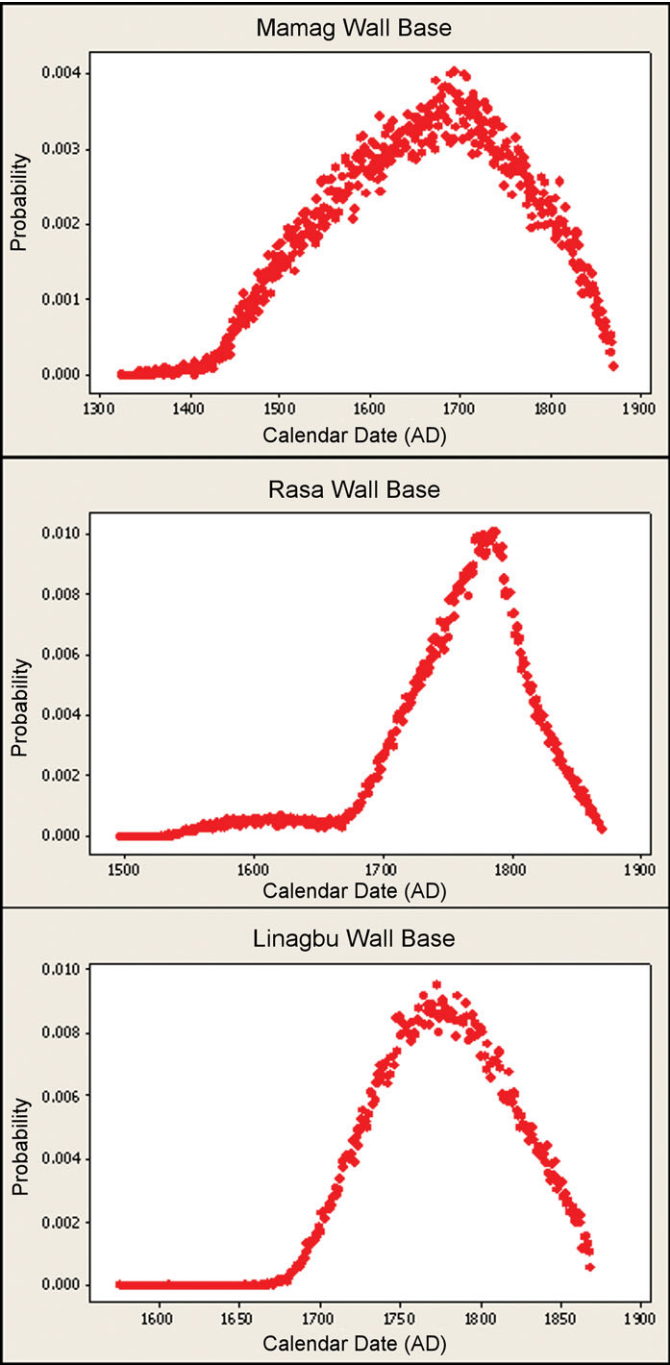


Figure 5. Posterior densities of terrace wall construction of the Bocos terrace system.

lowland areas before and during the contact period. These populations might have joined highland groups to avoid the Spanish colonisers.

This contention is supported by early estimates of populations and villages in lowland north-eastern Luzon. Fray Antonio Campo listed 100 lowland villages in Dupax, Nueva Vizcaya area in AD 1739. When Fray Antonio Antolin made a count in AD 1789, only 40 villages remained (Antolin 1789). Furthermore, the original Monforte expedition of AD 1660 listed 50 villages located higher on the Cordillera which still exist in the twentieth century (Scott 1974: 175).

The ^{14}C dates of this study do not preclude earlier agricultural terrace tradition in Ifugao territory (perhaps, taro). However, the extent of the rice terraces that we see today should be a product of historical population movements in c. AD 1500-1600. To put the question of Ifugao rice terrace antiquity to rest conclusively, sampling from different terrace systems and valleys should be undertaken and the results calibrated using Bayesian models similar to those developed here.

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References

- ACABADO, S. 2003. Land use and agricultural intensification: GIS-based analysis of the Ifugao landscape. Unpublished MA dissertation, University of Hawai'i.
- ANTOLIN, F. 1789. Notices of the pagan Igorots in 1789 (Translated by W.H. Scott). *Asian Folklore Studies* 29: 177-253.
- BARTON, R. 1919. Ifugao law (University of California Publications in American Archaeology and Ethnology 15). Berkeley & Los Angeles (CA): University of California Press.
- 1930. *The half-way sun*. New York: Brewer & Warren.
- BEYER, H.O. 1926. Recent discoveries in Philippine archaeology. *Proceedings of the Third Pan-Pacific Science Congress* 2: 2469-91.
- 1955. The origins and history of the Philippine rice terraces. *Proceedings of the Eighth Pacific Science Congress* 1: 387-98.
- BROSIOUS, P. 1988. Significance and social being in Ifugao agricultural production. *Ethnology* 27(1): 97-110.
- BUCK, C., J. KENWORTH, C. LITTON & A. SMITH. 1991. Combining archaeological and radiocarbon information: a Bayesian approach to calibration. *Antiquity* 65: 808-21.

- BUCK, C., C. LITTON & A. SMITH. 1992. Calibration of radiocarbon results pertaining to related archaeological events. *Journal of Archaeological Science* 19: 497-512.
- BUCK, C., W. CAVANAGH & C. LITTON. 1996. *The Bayesian approach to interpreting archaeological data*. New York: John Wiley & Sons.
- BUCK C.E., J.A. CHRISTEN & G.N. JAMES. 1999. BCal: an on-line Bayesian radiocarbon calibration tool. *Internet Archaeology* 7. Available at http://intarch.ac.uk/journal/issue7/buck_index.html
- CONKLIN, H. 1967. Some aspects of ethnographic research in Ifugao. *Transactions of the New York Academy of Sciences*, Series 2, 30(1): 99-121.
- 1972. *Land use in north central Ifugao*. New York: American Geographical Society.
- 1980. *Ethnographic atlas of Ifugao*. New Haven (CT): Yale University Press.
- DOZIER, E. 1966. *Mountain arbiters: the changing life of a Philippine hill people*. Tucson (AZ): University of Arizona Press.
- DYE, T.S. In press. Traditional Hawaiian surface architecture: absolute and relative dating, in T. S. Dye (ed.) *Research designs for Hawaiian archaeology: agriculture, astronomy and architecture*. Honolulu (HI): Society for Hawaiian Archaeology.
- EDER, J. 1982. No water in the terraces: agricultural stagnation and social change at Banaue, Ifugao. *Philippine Quarterly of Culture and Society* 10: 101-16.
- JOCANO, F.L. 2001. *Filipino prehistory: rediscovering pre-colonial heritage*. Quezon City: Punlad Research House Inc.
- KEESING, F. 1962. *The ethnohistory of northern Luzon*. Stanford (CA): Stanford University Press.
- KHA, N. 1965. *The forests of Pinus khasya and Pinus merkusii of central Vietnam* (Translated by Denys B. Fanshawe). Oxford: Commonwealth Forestry Institute.
- LADEFOGED, T. & M. GRAVES. 2008. Variable development of dryland agriculture in Hawai'i: a fine-grained chronology from the Kohala Field System, Hawai'i Island. *Current Anthropology* 49: 771-802.
- LAMBRECHT, F. 1967. The hudhud of Dinulawan and Bugan at Gonhadan. *Saint Louis Quarterly* 5: 527-713.
- 1962. *Religion of the Ifugao*. Manila: The Philippine Sociological Review.
- MAHER, R. 1973. Archaeological investigations in central Ifugao. *Asian Perspectives* 16(1): 39-70.
- SCHIFFER, M.B. 1986. Radiocarbon dating and the 'old wood' problem: the case of the Hohokam chronology. *Journal of Archaeological Science* 13: 13-30.
- SCOTT, W.H. 1974. *The discovery of the Igorots*. Quezon City: New Day Publishers.
- STUIVER, M. & H. POLACH. 1977. Reporting of ¹⁴C data. *Radiocarbon* 19(3): 355-63.
- TAYLOR, R.E. 1987. *Radiocarbon dating: an archaeological perspective*. Orlando (FL): Academic Press.
- UNESCO. 1995. Rice terraces of the Philippine Cordilleras. Available at http://whc.unesco.org/pg.cfm?cid=31&id_site=722