

## Impact case study (REF3)

<b>Institution:</b> University of Cambridge		
<b>Unit of Assessment:</b> UoA15 Archaeology		
<b>Title of case study:</b> Archaeological Contributions to Sustainable Farming and Food Security in China and India		
<b>Period when the underpinning research was undertaken:</b> May 2006 to December 2020		
<b>Details of staff conducting the underpinning research from the submitting unit:</b>		
<b>Name(s):</b>	<b>Role(s) (e.g. job title):</b>	<b>Period(s) employed by submitting HEI:</b>
Professor Martin Jones	Pitt-Rivers Professor of Archaeological Science	October 1990 to September 2018
Dr Tamsin O'Connell	Reader in Isotope Ecology	October 2004 to present
Dr Harriet Hunt	Research Associate	November 2004 to December 2014 & April 2015 to present
Dr Cameron Petrie	Reader in South Asian and Iranian Archaeology	September 2005 to present
Dr Adam Green	Research Associate	October 2016 to present
<b>Period when the claimed impact occurred:</b> August 2013 to December 2020		
<b>Is this case study continued from a case study submitted in 2014?</b> Yes		
<b>1. Summary of the impact</b> (indicative maximum 100 words)		
<p>Archaeological research at the University of Cambridge has shown the importance of past agricultural practices, especially cultivation of hardy, adaptable millets and use of sustainable water management practices, in semi-arid regions of Asia. As a result, as submitted for REF2014, the Aohan area of Inner Mongolia, China, was designated a <i>Globally Important Agricultural Heritage System</i> by the United Nations Food and Agriculture Organisation (FAO) in 2012. The full and ongoing benefit of this work has become manifest in Aohan since August 2013, with major increases in the growing of millet and corresponding improvements in the wellbeing of farmers. Since 2019, moreover, ongoing research has inspired new initiatives by the Indian Administrative Service and the Department of Rural Development and Panchayats, Government of Punjab to promote diversity in farming and resilient water management practices in order to improve sustainability in India.</p>		
<b>2. Underpinning research</b> (indicative maximum 500 words)		
<p>In 2008, Jones and Hunt co-authored an influential article on two Asian millet species, foxtail and broomcorn, highlighting their early cultivation across Eurasia [R1]. Jones' multidisciplinary group subsequently discovered that these millets were first cultivated at least 8,000 years ago in Inner Mongolia, northern China, with stable isotope analysis by O'Connell and colleagues providing direct evidence for their consumption by humans and animals in this region from the same date [R2]. Supported by a European Research Council (ERC) Advanced Grant for the <i>Food Globalisation in Prehistory</i> project, the team discovered genetic evidence from locally adapted cultivars showing that the diversity in broomcorn millet originated in western Inner Mongolia, close to an early site with archaeobotanical and isotope evidence for its use [R3]. Millets then spread throughout Eurasia, in particular along the mountain corridors of Inner Asia.</p> <p>Broomcorn and foxtail millets are hardy and well-adapted to semi-arid climates, with low water and nutritional requirements, and a demonstrated capacity for adaptive evolution in response to climatic challenges. Their short growing seasons made multi-cropping possible, which played a pivotal role in the development of settled societies and increased food security. Moreover, this property made millets suitable for the lifestyles of highly mobile pastoralists across northern China and Central Asia. They were subsequently incorporated into established agricultural systems in Europe and South Asia, fuelling dietary diversification and resilience to variable</p>		

conditions for agriculture [R4]. As a result of the research of Jones and colleagues, it is now recognised that millets are equally relevant to food security in semi-arid regions of China today (see Section 4).

With the retirement of Jones (October 2018), Petrie, Green and colleagues are taking the University of Cambridge's archaeological research on millet, other cereals and a widened perspective on Asian food security forward, with an emphasis on sustainable agriculture in India. Petrie's research, including the *TwoRains* and *Land, Water and Settlement* projects (funded by the ERC and the UK India Education and Research Initiative respectively), investigate adaptation to diverse environments in South Asia's Indus Civilisation, with a particular focus on how rural populations adapted their farming practices to survive in variable and changing environments [R5]. These approaches involved the flexible use of winter crops including wheat and barley, and summer crops including rice and millet. This diversity appears to have been resilient to short-term crises and enabled long-term sustainability [R5]. *TwoRains* has also established the efficacy of pond use for irrigation, going back 4,500 years.

The findings of this research have led to Global Challenges Research Fund award funding for Flagship Project 4 (FP4) of the *TIGR2ESS* (Transforming India's Green Revolution by Research and Empowerment for Sustainable Food Supplies) project. FP4 is using lessons from past agricultural and water management practices to inform shifts towards more sustainable farming in India. It has identified a progressive reduction in crop diversity over the last 1,500 years, and a precipitous decline in pond and tank use over the last 50 years. The project is encouraging the importance of millet as a drought-resistant crop. It is also promoting efficient water management, especially the renewed use of village ponds (fed by surface water) for irrigation, to enhance the sustainability of farming practices that are today on the edge of crisis due to depletion of groundwater from aquifers [R6].

### 3. References to the research (indicative maximum of six references)

[R1] Hunt, H.V., Vander Linden, M., Liu, X., Motuzaite-Matuzeviciute, G., Colledge, S., Jones, M.K., 2008. Millets across Eurasia: Chronology and context of early records of the genera *Panicum* and *Setaria* from archaeological sites in the Old World, *Vegetation History and Archaeobotany* 17, 5. <https://doi.org/10.1007/s00334-008-0187-1>. (Peer reviewed international journal article; research supported by a Wellcome Trust Bioarchaeology Fellowship (2006 to 2010) of GBP237,115 to Hunt and Jones for the project Modelling Agricultural Origins: Do the Minor Crops Challenge the Conclusions Drawn from the Major Crops?)

[R2] Liu, X., Jones, M.K., Zhao, Z., Liu, G., O'Connell, T.C., 2012. The earliest evidence of millet as a staple crop: New light on Neolithic foodways in North China, *American Journal of Physical Anthropology* 149, 283-290. <https://doi.org/10.1002/ajpa.22127>. (Peer reviewed international journal article)

[R3] Hunt, H., Rudzinski, A., Jiang, H., Wang, R., Thomas, M., Jones, M., 2018. Genetic evidence for a western Chinese origin of broomcorn millet (*Panicum miliaceum*), *The Holocene* 28, 1968-1978. <https://doi.org/10.1177%2F0959683618798116>. (Peer reviewed international journal article; research supported by an ERC Advanced Grant (2010 to 2015) of EUR1,979,000 (GBP1,735,966) to Jones for the project Food Globalization in Prehistory; REF2 submission)

[R4] Jones, M.K., Hunt, H.V., Kneale, C.J., Lightfoot, E., Lister, D.L., Liu, X., Motuzaite-Matuzeviciute, G., 2016. Food globalization in prehistory: The agrarian foundations of an interconnected continent, *Journal of the British Academy* 4, 73-87. <https://doi.org/10.5871/jba/004.073>. (2015 Elsley Zeitlyn Lecture on Chinese Archaeology and Culture; research supported by the above-mentioned ERC Advanced Grant and a Leverhulme Trust grant (2010 to 2013) of GBP140,243 to Jones for the project Pioneers of Pan-Asian contact: Early Farmers and the Trail of Broomcorn Millet)

[R5] Petrie, C.A., Singh, R.N., Bates, J., Dixit, Y., French, C.A.I., Hodell, D.A., Jones, P.J., Lancelotti, C., Lynam, F., Neogi, S., Pandey, A.K., Parikh, D., Pawar, V., Redhouse, D.I., Singh, D.P., 2017. Adaptation to variable environments, resilience to climate change: Investigating land, water and settlement in Indus northwest India, *Current Anthropology* 58, 1-30.

<https://doi.org/10.1086/690112>. (Peer reviewed international journal article; research supported by an ERC Consolidator Grant (2015 to 2021) of EUR1,999,439 (GBP1,538,030) to Petrie for the project TwoRains (Winter Rain, Summer Rain: Adaptation, Climate Change, Resilience and the Indus Civilisation), and by a UK India Education and Research Initiative award (2007 to 2011) of GBP148,140 to Petrie for the Land, Water and Settlement project (From the Collapse of Harappan Urbanism to the Rise of the Great Early Historic Cities); REF2 submission)

[R6] Green, A.S., Dixit, S., Garg, K.K., Sandya, N., Singh, G., Vatta, K., Whitbread, A.M., Jones, M.K., Singh, R.N., Petrie, C.A., 2020. An interdisciplinary framework for using archaeology, history and collective action to enhance India's agricultural resilience and sustainability, *Environmental Research Letters* 15, 105021. <https://doi.org/10.1088/1748-9326/aba780>. (Peer reviewed international journal article; research supported by a BBSRC Global Challenges Research Fund grant (2017 to 2021) of GBP7,035,021 (GBP278,468 specifically to Petrie as co-investigator) for the TIGR2ESS (Transforming India's Green Revolution by Research and Empowerment for Sustainable Food Supplies) project)

#### 4. Details of the impact (indicative maximum 750 words)

Drawing on University of Cambridge research, millet cultivation is being successfully promoted as a heritage agricultural system and a route to both increased food security and sustainable cash-cropping in Inner Mongolia, China. A key intermediary step in this process was designation in 2012 of the Aohan dryland farming system as a *Globally Important Agricultural Heritage System* (GIAHS) by the FAO. This past development was submitted as impact for the previous REF cycle. Since August 2013, both ongoing research and the results of GIAHS designation are now having a major influence on agricultural practices on the ground in Inner Mongolia. In recognition of this impact, the Aohan Government awarded a medal to Jones in September 2016, honouring him and several others for studying, preserving and developing millet agriculture in Aohan [E1].

The economic impact of a new emphasis on millet cultivation in Aohan is clear from data regarding annual production (in metric tons) by province, which are available from the National Bureau of Statistics of China [E2]. Five of the six provinces that have the highest production of millet in China show only slow growth over the previous decade. However, from 2014 the millet harvest in Inner Mongolia has increased substantially, reaching a peak of 766,200t in 2017, rising from 304,700t in 2013 (Figure 1).

Already in 2014, Chinese news reporting explicitly linked this increase in millet production, together with its associated impact on the wellbeing of farmers, to the Cambridge-based archaeological research of Jones and colleagues [E3]. The price paid to farmers for millet also improved. In September 2012, the purchase price of Aohan millet was CNY1.8/kg (GBP0.18/kg). Two years later, the purchase price of millet rose to CNY4.5/kg (GBP0.46/kg); a special gift of selected millet cost up to CNY80/kg (GBP8.15/kg) (currency conversions match the date of the news article: 23 October 2014) [E3,E4]. Moreover, one can now find well-packed and branded Aohan millet in supermarkets across China; its cultivation has government backing and the importance of millet farming continues to grow in the region, with corresponding improvements in the wellbeing of farmers [E4].

In December 2015, Jones and colleagues were awarded the prestigious Shanghai Archaeological Forum Research Award for their study of the origins and spread of broomcorn and foxtail millets, and resulting impacts on today's millet farmers [E5]. Looking forward, the global potential of broomcorn millet, including for the European and US markets, is now recognised by agronomists, with explicit acknowledgement of the impact of Jones' archaeological research [E6].

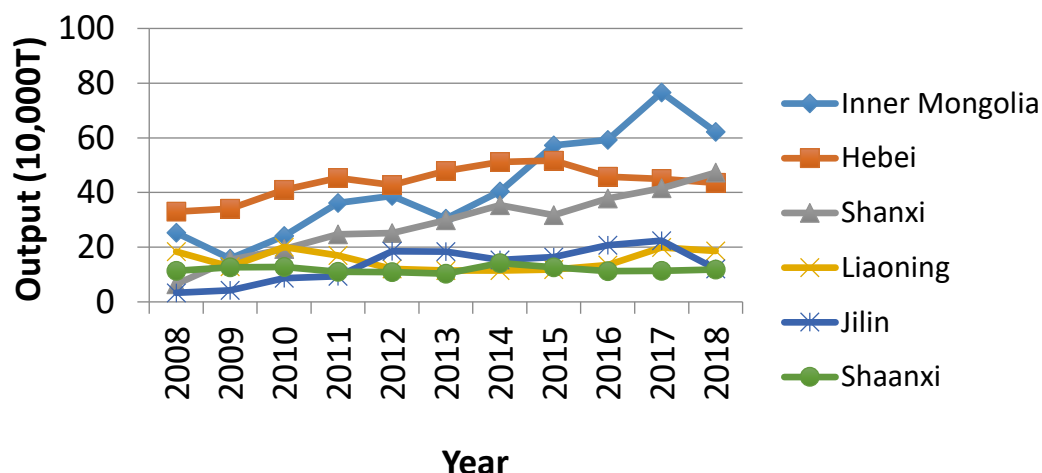


Figure 1: Millet output per year in six Chinese provinces, from 2008 to 2018, showing change in Inner Mongolia [E2]. Post-2018 data are not available as of December 2020.

Turning to India, the potential importance of millet production, and of other resilient and sustainable agricultural practices documented by archaeology, is being actively promoted by the research of Petrie and colleagues at the University of Cambridge, in collaboration with partners in India. Building on data regarding prehistoric cropping regimes and water management, collected by the *Land, Water and Settlement* and *TwoRains* projects, FP4 of *TIGR2ESS* is promoting the use of millet as a water efficient crop and advocating the renovation of historic ponds and related water collection infrastructure as a route to sustainable water use in the agriculture sector in Punjab and Haryana. This programme for action has now been adopted in Punjab. After engaging with the *TIGR2ESS* project, including meetings at the McDonald Institute for Archaeological Research in November 2019, the Chief Principal Secretary of the Chief Minister of Punjab (having specific responsibilities for policies and programmes concerning agriculture and rural economy) responded:

*Before reaching Cambridge, the question that was being asked was: what has archaeology to do with agriculture? But the questions often raised ... about loss of crop diversity and eco-diversity can perhaps only be substantively answered through archaeological evidence that proves what has changed in living things both plants and animal life over a period of time and how? The findings from the TwoRains and TIGR2ESS project research have highlighted the decline in crop diversity over time, and the clear reduction in the range of choice for farmers who historically engaged in very diverse multi-cropping farming. The abandoning of important arid adapted crops like millet is particularly compelling, as such crops might be effectively reintroduced into the farming systems of Punjab to increase diversity and sustainability [E7].*

Moreover, in January 2020 a stakeholder consultation on water bodies was held in Ludhiana, Punjab, organized with Punjab Agricultural University, International Crops Research Institute for the Semi-Arid Tropics, Centers for International Projects Trust (New Delhi) and the University of Cambridge. It brought together *TIGR2ESS* researchers, including Petrie and Green, with representatives of the Department of Rural Development and Panchayats, Punjab, and other stakeholders to plan for sustainable irrigation practices influenced by archaeological findings [E7,E8,E9]. The Chief Principal Secretary of the Chief Minister of Punjab explains further:

*The insights into the decline in the use of village ponds and water tanks that came from the Cambridge visit encouraged me to organise a workshop on village ponds and water bodies, which was held in Ludhiana, Punjab, India. The workshop served to introduce these new insights into India's recent and deeper past to civil servants, policymakers, and stakeholders. In particular, the workshop served as a platform to introduce the archaeological findings to civil servants and researchers who will now*

*be able to work together to identify strategies for renovating village ponds across Punjab, so that they produce a sustainable and manageable water source ... [E7].*

As a result, the Department of Rural Development and Panchayats, Punjab, has already (to 3 August 2020) funded 114,663 person days clearing all 884 village ponds in the Ludhiana District, at a cost of INR89,462,311 (GBP911,621 on 3 August 2020). The ponds were made ready to contain monsoon rainwater for the purposes of agriculture, fisheries and recharging groundwater. This major initiative, introduced during COVID restrictions, also provided work for those made unemployed during the pandemic [E10].

#### 5. Sources to corroborate the impact (indicative maximum of 10 references)

[E1] Letter: Jones among those recognised by the government of Aohan, Inner Mongolia, China, for having developed millet agriculture and promoted economic wellbeing. Language: Chinese

[E2] Website: National Bureau of Statistics of China. Annual Millet Production (in 10,000t) by Region. <http://data.stats.gov.cn/english/easyquery.htm?cn=E0103>

[E3] News article (People's Daily): When Did Human Cultivation of Millet Originate? <http://culture.people.com.cn/n/2014/1023/c22219-25892144.html>. Language: Chinese

[E4] Testimonial: Deputy Chair, School of Cultural History, Chifeng University, Inner Mongolia

[E5] Website: Second Shanghai Archaeology Forum (i) World's Major Archaeological Discoveries and Research Announced [www.kaogu.cn/en/News/Academic\\_activities/2015/1214/52376.html](http://www.kaogu.cn/en/News/Academic_activities/2015/1214/52376.html); (ii) The Origin and Spread of Broomcorn and Foxtail Millets [www.kaogu.cn/en/Special\\_Events/dierjieshanghailuntan/2015/1225/52552.html](http://www.kaogu.cn/en/Special_Events/dierjieshanghailuntan/2015/1225/52552.html)

[E6] Journal article: Das, S., Khound, R., Santra, M., Santra, D.K., 2019. Beyond bird feed: Proso millet for human health and environment, *Agriculture* 9, <https://doi.org/10.3390/agriculture9030064>. See page 14.

[E7] Testimonial: Chief Principal Secretary of the Chief Minister of Punjab

[E8] Report: 2020. *Stakeholder consultation. Village ponds and irrigation in Punjab: The modern utility of an ancient water management strategy, January 19 2020*, Punjab Agricultural University, Ludhiana

[E9] News article (The Indian Express): Ludhiana: Experts, Stakeholders Attend Discussion at PAU on Revival of Village Ponds <https://indianexpress.com/article/cities/ludhiana/ludhiana-experts-stakeholders-attend-discussion-at-pau-on-revival-of-village-ponds-6225653/>

[E10] News article (The Tribune): Rs 8.95 cr Spent on Cleaning of 884 Village Ponds in Ludhiana District <https://www.tribuneindia.com/news/ludhiana/rs-8-95-cr-spent-on-cleaning-of-884-village-ponds-in-ludhiana-district-ddpo-121865>