Institution: University of Birmingham

Unit of Assessment: UoA 5 - Biological Sciences

Title of case study: Agrobiodiversity Conservation for Food Security

1. Summary of the impact (indicative maximum 100 words)

Food Security is one of the major global challenges confronting mankind. The Birmingham **Plant Genetic Resource Group's (PGR)** research and its contribution to policy implementation are helping to secure food supplies, mitigate the impact of climate change and maintain consumer choice, thereby impacting governments, commercial breeders, farmers and the public alike. PGR research on the development and implementation of agrobiodiversity conservation strategies, specifically on crop wild relatives' (CWR) and landraces' (LR) *in situ* and *ex situ* conservation, has helped national and international agencies meet their convention and treaty obligations, and underpinned food security. Their work has provided the necessary scientific foundation for global, European and UK impact: assisting the UN Food and Agriculture Organisation establish a global network for CWR *in situ* conservation, the European Commission create an inventory of traditional crop varieties and the UK government inclusion of CWR and LR diversity in environmental stewardship schemes, actions taken on the basis of the group's advice.

2. Underpinning research (indicative maximum 500 words)

Agrobiodiversity and specifically the conservation of genetic diversity within crop wild relatives (CWR) and landraces (LR) are essential because of the beneficial traits that can be transferred from CWR and LR into modern varieties. A recent analysis by Pricewaterhouse Coopers (press release July 2013) values the current value of CWR-derived crops to be as much as $68 billion and likely to triple in the future. Despite this, agrobiodiversity conservation has historically been largely *ad hoc* and thus not fit for purpose in relation to current and future demands. Work over the past 20 years by the Birmingham Plant Genetic Resource Group (PGR) led by Dr Nigel Maxted (Senior Lecturer) and Professor Brian Ford-Lloyd (Professor of Plant Conservation Genetics to May 2013, subsequently Emeritus) has had a substantial impact supplying the scientific foundation for robust conservation strategies and associated policies resulting in enhanced exploitation. This research has been funded by EU FP5 Research (PGR Forum), Defra (UK LR inventories), EU FP6 Research (Diverseeds), EU Gen Res (AEGRO), EU IUCN (Threat Red Listing), Defra SAIN (Chinese CWR Conservation), EU FP7 Research (PGR Secure), Global Crop Diversity Trust (Global CWR situ conservation), EU INCO (Jordanian conservation), Norwegian Gov. (CWR conservation), EU ACP Science and Technology Programme and 16 PhD studentships.

Although extensive *ex situ* holdings of key crops (wheat, rice and maize) in gene banks do adequately represent their natural genetic diversity, this is not the case for CWR or LR of all minor and even some major crops (barley, sorghum, millet and beans). Moreover, a comprehensive global *ex situ* sampling approach would be economically unfeasible. Hence, it is important to be able to prioritise species and populations under threat or those most likely to yield superior traits. Research by the PGR group has developed strategies that provide a systematic framework to CWR and LR conservation by extending gap analysis, an ecosystem conservation methodology to agrobiodiversity. This involves: (i) identifying target taxon and target area; (ii) assessment of natural intrinsic taxonomic, genetic and ecogeographical diversity, and threat assessment; (iii) review of current complementary *in situ* and *ex situ* conservation strategies; and (iv) reformulation of the conservation strategy by finding the 'gaps' between natural, intrinsic diversity and that diversity already effectively conserved *in situ* and *ex situ*.

Through their work the group have defined the minimum requirements for conservation and utilisation of CWR, identifying global conservation priorities in relation to fulfilling the requirement for Food Security. Coupled with this the PGR group have pioneered approaches for generating CWR and LR conservation inventories that are readily accessible to stakeholders using web-enabled databases. The group have demonstrated how the use of genetic markers and new technologies, such as transcriptomics, can be integrated into agrobiodiversity programmes, for instance through the identification of genes that can contribute to the mitigation of climate change. The PGR group are currently lead partners in an EU Seventh Framework Programme which links

all elements of their CWR and LR conservation, phenomics/genomics, informatics and end-user engagement (EU FP7 THEME KBBE.2010.1.1-03, PGR Secure 'Characterization of biodiversity resources for wild crop relatives to improve crops by breeding').

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

1. Sawkins, M.C., Maass, B.L., Pengell, B.C., Newbury, H.J., Ford-Lloyd, B.V., Maxted, N. and Smith, R. (2001) Geographical patterns of genetic variation in two species of Stylosanthes Sw. Using amplified fragment length polymorphism. Molecular Ecology, 10: 1947-1958. doi: 10.1046/j.0962-1083.2001.01347
2. Maxted, N., Dulloo, E., Ford-Lloyd, B.V., Iriondo, J. and Jarvis, A., (2008) Gap analysis: a tool for more effective genetic conservation assessment. Diversity and Distributions, 14: 1018-1030. doi: 10.1111/j.1472-4642.2008.00512
3. Moore, J.D., Kell, S.P., Iriondo, J.M., Ford-Lloyd, B.V. & Maxted, N., (2008) CWRML: representing crop wild relative conservation and use data in XML. BMC Bioinformatics, 9: 116. doi: 10.1186/1471-2105-9-116
4. Ford-Lloyd, B.V., Schmidt, M., Armstrong, S.J., Barazani, O., Engels, J., Hadas, R., Hammer, K., Kell, S.P., Kang, D., Khoshbakht, K., Li, Y., Long, C., Lu, B., Ma, K., Nguyen, V.T., Qiu, L., Ge, S., Wei, W., Zhang, Z. and Maxted N., (2011) Crop Wild Relatives—Undervalued, Underutilized, and under Threat? *Bioscience*, 61(7): 559-565. doi: 10.1525/bio.2011.61.7.10
5. Maxted, N., Kell, S.P., Ford-Lloyd, B.V., Dulloo, M.E. and Toledo, A., (2012) Toward the systematic conservation of global crop wild relative diversity. *Crop Sciences*, 52(2): 774-785. doi: 10.2135/cropsci2011.08.0415
6. Vincent, H., Wiersema, J., Kell, S.P., Dobbie, S., Fielder, H., Castañeda Alvarez, N.P., Guarino, L., Eastwood, R., León, B. and Maxted, N., (2013). A prioritized crop wild relative inventory to help underpin global food security. *Biological Conservation*, 167: 265-275. doi.org/10.1016/j.biocon.2013.08.011

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

The development and implementation of agrobiodiversity conservation strategies, specifically on crop wild relatives (CWR) and landraces (LR) *in situ* and *ex situ* conservation by the Biosciences PGR research group have had impact via both commissioned research from leading international and national bodies and through leadership of key committees and working groups. Particularly noteworthy is the contribution and influence of Dr Maxted's expertise in relation to the activities of the United Nations Food and Agriculture Organization (FAO). FAO, founded in 1943, recognised the need to maintain agrobiodiversity to sustain its exploitation through plant breeding and other forms of plant utilisation. This need to link conservation to utilisation was reiterated in the Convention on Biological Diversity (1992) and the International Treaty on Plant Genetic Resources for Food and Agriculture (PGRFA) (2001), both of which placed an obligation on policymakers to systematically conserve national, European and international CWR and LR genetic diversity. In 2011, the PGR group made a significant contribution to the FAO's Second Global Plan of Action for PGRFA when their research was used as the basis for *in situ* conservation and management of LR and CWR which forms one of the four priority areas in the plan. Translation of the research is providing practical tools to help national agrobiodiversity agencies throughout the world develop systematic conservation and use strategies, such as the creation of effective national strategies for CWR and landrace conservation, which in implementation promote their use in underpinning food security. The influence of the PGR group continues, with Dr Maxted providing scientific oversight for the establishment led by FAO Commission on Genetic Resources for Food and Agriculture (CGRFA) of a global network for *in situ* conservation (FAO, 2013). *FAO recognise the significant impact stretching back to the 1980's of Maxted's research and scientific leadership on global conservation and use of plant genetic resources, especially in developing in situ conservation methodologies and practical tools, which have been used to underpin global food security (s1, s2).*

The national conservation techniques developed by the PGR Group have now been or are being applied through the EU FP7 funded PGR Secure project (2010-2014) (http://www.pgrsecure.org/)

to conserve and promote use of agrobiodiversity in Albania, Azerbaijan, Belarus, Bulgaria, Cyprus, Czech Rep., Finland, Greece, Ireland, Italy, Portugal, Norway, Spain, Sweden and United Kingdom, as well as countries in Africa, South America, Central Asia, China and the Middle East. *The Director General of Bioversity International has recognised Maxted's work with their regional offices in West Asia and North African and Sub-Saharan Africa on technology transfer and practical conservation (s3). He also notes Maxted's research leadership in European plant genetic resource conservation through his chairing of committees and obtaining of research funding, recently EU FP7 PGR Secure, which has assisted national programmes in Europe to develop CWR conservation strategies and action plans, as well as closer links between the conservation and user communities to generate both sustainability and commercial benefits.* Experience gained from PGR Secure has also been used by the European Parliament 'Technical options for feeding 10 billion people' which investigates options for greater integration of plant genetic resource conservation and crop breeding *(s4)*.

The PGR group's research is also achieving policy and practical effects through work with the Species Survival Commission (SSC). The SSC is part of the International Union for Conservation of Nature (IUCN) which was founded in 1948 and describes itself as the world's oldest and largest global environmental organization. PGR interaction with SSC has led to the establishment of the first global priority list of CWR species based on their value as actual or potential trait donors for breeding and climate change mitigation; the production of checklists for the countries of Armenia, Bolivia, China, Madagascar, Sri Lanka, Uzbekistan, among others; the gap analysis of 174 major crop gene pools and the development of appropriate conservation strategies; the publication of a CWR manual for *in situ* conservation and a toolkit to help national and regional agencies plan agrobiodiversity conservation; and coordination of the development of national and regional conservation strategies at an international meeting held in Palanga, Lithuania (Sept 2011) attended by 110 agrobiodiversity conservationists from 43 countries. The meeting fundamentally changed the way agrobiodiversity is conserved. There was a shift from an *ad hoc* approach where each country acted independently and agrobiodiversity was widely under-conserved, to a more scientific approach where each country systematically conserves its most important agrobiodiversity (those most likely to have exploitation potential) and countries in turn collaborate to ensure regional and ultimately global conservation of the species that are perhaps of highest priority in sustaining humankind; this is now referred to as the provisioning ecosystem service. *The SSC Chair notes that most conservation work is focused at the ecosystem and species level, but confirms the extent of Maxted's leadership and impact in conservation at the genetic level within species, researching the threat facing the 1,300 priority species and making the link between conservation and utilisation, so ensuring the conserved diversity is maintained and used by plant breeders and other users to benefit and safeguard humankind (s5).*

Further the PGR group's research is playing an important role in the developing world, through collaboration with Bioversity International in Italy, International Centre for Tropical Agriculture in Colombia and the International Centre for Agricultural Research in Dry Areas in Syria, each of them members of the Consultative Group on International Agricultural Research who are independent, non-profit research organizations whose remit is to undertake innovative agricultural research on behalf of poor people in developing countries. The PGR group are contributing expertise on practical conservation and technology transfer for a wide range of crop species in Africa, South America, Central Asia, China and the Middle East. Most recently, in 2009 Maxted played a central role in formulating and implementing a new $50 million project funded by the Government of Norway (*s6*). This massive effort is focused on permanently conserving the genetic diversity of the wild plants that are most closely related to the world's most important crops. The rationale is to protect and make available the genetic diversity that underpins important ecological characteristics in wild plants, with a view to introducing them into key crops, either by conventional plant breeding or by genetic engineering. The PGR group was responsible for researching the first global priority list of 1,647 crop wild relative taxa that were most likely to be used by plant breeders (http://www.cwrdiversity.org/checklist/) and identify where globally these species required *ex situ* or *in situ* conservation. *The former Director of the Royal Botanic Gardens, Kew, acknowledges the central role Maxted played in planning and implementing this critical global project and comments that "Dr. Maxted is one of the world experts in the important work of conserving plant genetic resources to underpin food security for the future" (s7).*

Closer to home the PGR group's research is underpinning CWR and LR conservation in the UK and Europe. In his role as Chair of the UK PGR Group (Defra Committee), Maxted oversees UK PGR policy and conservation implementation. The results from the Birmingham led UK inventory of crop landrace diversity project which is on-going, has contributed to the UK's national report to the FAO on the state of the UK's Plant Genetic Resources for Food and Agriculture (2009). Maxted has played an instrumental role in establishing the Scottish Landrace Protection Scheme for the Scottish Executive and jointly wrote the English CWR Conservation Strategy document published by Natural England. The latter led to joint work with Natural England to designate the first European genetic reserve for *in situ* CWR conservation in the Lizard National Nature Reserve in Cornwall. *The Defra lead on PGR concludes "Both these lines of work helped secure the UK's commitments to Aichi Target 13 agreed by the CBD Conference of Parties in Nagoya in 2010 and was subsequently reflected in England's Biodiversity Strategy 2020 which contains explicit commitments to conserve both wild relatives and landrace" (s8).*

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

s1. The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture, Food and Agriculture Organisation of the United Nations, Rome, 2010.

s2. Senior Policy Officer, Agricultural Production and Protection Division, Food and Agriculture Organisation of the United Nations, Rome, Italy; letter, dated 9th November 2012.

s3. Director General, Bioversity International, Consultative Group for International Agricultural Research, Rome, Italy; Letter dated 20th Feb 2013.

s4. Technical options for feeding 10 billion people. Sustainable intensification of crop production: climate change and agriculture; biodiversity and agriculture (2013). Report prepared for the STOA Panel of the European Parliament. Contract IP/A/STOA/FWC/2008-096/LOT3/C1/SC5, European Parliament Science and Technology Options Assessment STOA. http://www.europarl.europa.eu/stoa/cms/studies.

s5. Chair IUCN Species Survival Commission, Bath, UK; Letter dated 26th Feb 2013.

s6. "Adapting agriculture to climate change: new global search to save endangered crop wild relatives" Press Release, 9/12/2010 from Global Crop Diversity Trust.

s7. Dean of the School of Forestry & Environmental Studies and Professor of Botany, Yale University, New Haven, CT, USA; Letter dated 15th March 2013.

s8. ABS and Agricultural Plant Genetic Resources, Dept for Environment Food and Rural Affairs, London, UK; Letter dated 27th March 2013.