Institution: University of Plymouth

Unit of Assessment: UoA14

Title of case study: Turning environmental forensic evidence into effective soil conservation policy

Period when the underpinning research was undertaken: 2012-2019

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Professor William Blake	Professor of Catchment Science	2003 to present
Dr Claire Kelly	Senior Research Fellow	2010 to present
Dr Alex Taylor	Technical specialist and Research Fellow	2014 to present

Period when the claimed impact occurred: 2014-11.11.20

Is this case study continued from a case study submitted in 2014? N

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

Soil erosion is a global challenge that has serious socio-economic consequences for food, water, energy and environmental security. Blake and Taylor have developed environmental forensic techniques that reveal linkages between unsustainable farming and forestry practices and soil erosion and downstream sedimentation. Working with the *Joint UN FAO/IAEA Division of Nuclear Techniques in Food and Agriculture*, they have developed tools that generate tangible evidence, which has been applied to change soil conservation policy and practice, to the benefit of soil conservation and socio-economic wellbeing in the Global South. Blake, Kelly and collaborators have also developed and implemented an interdisciplinary methodology that measures the social and cultural impacts of soil erosion, which has facilitated co-production of community-owned change to more sustainable land management practices on the international stage.

2. Underpinning research (indicative maximum 500 words)

Soil is a fundamental resource that is being lost from cropland at a rate of 12 million hectares p.a. world-wide, as a consequence of unsustainable agricultural and forestry practices. Erosion and downstream sedimentation have a major impact on food, water and energy security, and yet the linkages between these are poorly understood, and often not clearly defined or recognised in land management strategies. Closing this gap is a key focus of our research [3.1].

Environmental forensic tools using isotopic soil and sediment tracers can be used to identify soil erosion hotspots. Cultivation and other land management practices alter isotopic properties of topsoil and such differences can be used as 'fingerprints' to track and trace soil movement through land-water systems. These 'nuclear techniques' have been promoted by the *UN Food and Agricultural Organisation* in partnership with the *International Atomic Energy Agency (UN FAO/IAEA)* to be used both as a decision support tool and a vehicle to develop capacity for land management change in the Global South. Blake and Taylor played a lead role in developing the focus and direction of specific techniques, creating tangible science policy development and soil conservation policy impacts in the Global South, through:

i. developing new techniques to identify land-use specific erosion hotspots [3.2];
ii. developing tools to quantify erosion patterns and amounts [3.3, 3.4, 3.5];

iii. delivering specialist training to developing country scientists [3.1, 3.3];

Most recently, Blake and Kelly further recognised that influencing soil management through a 'top-down' approach i.e. via government policy is not always sufficient/effective to deliver changes to soil conservation practices in situ, particularly in the erosion-prone and degraded landscapes in the Global South. In these environments, a complex interplay of environmental, political, governance and socio-cultural factors place huge pressures on natural resources. In response, Blake, Kelly and collaborators:

i. developed an interdisciplinary research methodology to enable co-design of changes to land management practices between natural and social scientists and the local community [3.6] which overcomes common implementation gaps

On the technical side (i-iii above), the team has led innovative work around the short-lived fallout radionuclide, beryllium-7 (Be-7) (summarised in 3.4), which comes down with rainfall and can be used to detect soil movement, export or loss. Through specialist training provision synthesised in an IAEA publication [3.3], they harmonised the application of this approach to support soil conservation strategies, exemplified in national forestry management policy change in Morocco [3.3].

Blake provided the first real-world research application of Compound-Specific Stable Isotope (CSSI) markers in an agricultural river basin context [3.2], a concept promoted by the Joint UNFAO/IAEA programme, in 2012. The research demonstrated how isotopic biomarkers transferred from plant to soil can be used to identify crop-specific soil erosion hotspots, in this case identifying the disproportional impact of eroding grazing land damaged by livestock.

Blake has actively enhanced the impact of nuclear forensic techniques for food and water security through targeted training courses [3.2] for African, south east Asian and Latin American UN FAO/IAEA networks, both in the IAEA Laboratories at Seibersdorf, Austria, and through hosting UN-sponsored Research Fellows at Plymouth's ISO-certified Consolidated Radioisotope Facility.

Recent UKRI GCRF-funded interdisciplinary research [3.6] in Tanzania has merged environmental forensics evidence into a collaborative interdisciplinary approach to co-create change. Working with resident Maasai and local council officers, research demonstrated that extreme drought and focussing of livestock have increased susceptibility to soil erosion. Interviews revealed barriers to change, such as lack of resources and motivation for a community-based approach to land protection. The findings informed a solution that puts the Maasai at the centre of decision-making, and helped co-create a new land management policy designed to adapt to the needs of different communities and locations. This work is ongoing through a GCRF NERC-BBSRC 'Research Translation' third phase. The project was 'runner up' in the Guardian Universities Award 2020 for 'Internationalisation' and is a finalist in the Green Gown Awards 2020 in the 'Research with Impact' category.

From 2016 to present, Plymouth scientists have been expert members of the Co-ordinated Research Programme (CRP) *Nuclear Techniques for a Better Understanding of the Impact of Climate Change on Soil Erosion in Upland Agro-Ecosystems*, and have written specific Be-7 guidelines. Capacity building within this CRP was augmented by the European Commission IMIXSED project [3.1] which brought together EU isotopic techniques with US Bayesian modelling for improved assessment and management of global sedimentation problems.

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

3.1 **Blake WH**, Boeckx P, Stock BC, et al (2018) A deconvolutional Bayesian mixing model approach for river basin sediment source apportionment. Sci Rep 8:13073:1–12

3.2 **Blake WH**, Ficken KJ, Taylor P, Russell MA, Walling DE (2012) Tracing crop-specific sediment sources in agricultural catchments. Geomorphology 139:322–329

3.3 Mabit, L., **Blake**, **W**. (2019). Assessing recent soil erosion rates through the use of beryllium-7 (Be-7), Springer International Publishing. https://doi.org/10.1007/978-3-030-10982-0
3.4 **Taylor A**, **Blake WH**, Smith HG, Mabit L, Keith-Roach MJ (2013) Assumptions and challenges in the use of fallout beryllium-7 as a soil and sediment tracer in river basins. Earth-Science Rev 126:85–95
3.5 **Taylor A**, **Blake WH**, Keith-Roach MJ (2014) Estimating Be-7 association with soil particle size fractions for erosion and deposition modelling. J Soils Sediments 14:1886–1893
3.6 **Blake W**, Rabinovich A, Wynants M, et al (2018) Soil erosion in East Africa: an interdisciplinary approach to realising pastoral land management change. Environ Res Lett. doi: 10.1088/1748-9326/aaea8b

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

Through their direct contribution to the three components of the Joint UN FAO/IAEA research-to-practice framework (i.e. research development, practical application, capacity building), Plymouth scientists have made a fundamental contribution to delivering changes in soil management policy and practice at the catchment scale. As stated by the Section Head at UN FAO/IAEA, *"Your research has made a major contribution to the focus and direction of nuclear techniques to support soil conservation policy, and has contributed to fundamental changes in soil management policy and practice at the catchment scale within three of our Member states: Vietnam, Malaysia and Morocco. These success stories highlight the importance of the research-to-practice framework in helping to address the global challenge of soil erosion."* [5.1].

The impact of these contributions on soil conservation are evidenced in four of the Joint UN FAO/IAEA Member state countries: from top-down science-into-policy impact in Morocco, Vietnam, Malaysia to bottom-up community-driven change in Tanzania.

4.1 Changed soil management policy and practice at the government level: Vietnam, Malaysia and Morocco

Drawing on his research, Blake led two training programmes in 2014 [5.2] and 2016 [5.3] for visiting Research Fellows from Member states of the UN FAO/IAEA. These two programmes engaged 46 Fellows from Member states across South America, Africa, South East Asia and Eastern Europe. The IAEA highlighted the significance of the 2014 training event in new techniques and approaches for soil conservation management that led to impact: "*Through this training, the integrated and combined use of FRNs and CSSI techniques was introduced for the first time on a world wide scale … [to improve] the cost-effectiveness of soil conservation at catchment level, and placing soil erosion control measures where most needed (precision soil conservation)*" [5.2]. The success and influence of this training has been significant, leading directly to changes in policy and practice at the government level in the three Member states of Vietnam, Malaysia and Morocco, with resultant benefits for soil conservation and water resource management on the ground, as evidenced by the following case studies:

1. *Southeast Asia:* Blake's pioneering work on CSSI tracers and dissemination activities was applied to deliver changes in soil conservation practices in Vietnam and Malaysia [5.4], to the benefit of soil and water resource management in both countries. In Vietnam, trained scientists used CSSI tools to assess the influence of land use practices on lowland water quality and identify hotspots of land degradation enabling implementation of cost-effective conservation strategies (2013-2014) that reduced soil erosion in uplands by 90% and retained sufficient runoff water for lowland rice production. This change in land management practice and reduction in soil erosion has had important socio-economic impacts at the scale of the individual farmer. One farmer reported an increase in income of over 20%: *"Thanks to nuclear techniques used in determining the exact cause and source of soil erosion, his land is now stable, and his coffee plantation profitable"* [4]. In Malaysia, attempts to tackle sedimentation rates in lakes were hampered by lack of information on dominant sediment sources; however, the CSSI tool enabled

scientists to identify the exact source of the sediments, allowing for proper soil erosion mitigation measures to be undertaken in cooperation with the State Agriculture Department [5.4].

4.1.2 Morocco: Blake's development and provision of training support in the use of Be-7 as an isotopic tracing tool [1, 6] enabled Moroccan scientists to change forestry management practice in Morocco: *"Using isotopic techniques, we were able to accurately assess soil erosion and the effectiveness of soil conservation practices and make concrete recommendations to policymakers."* (Head of the Forestry Research Centre of Morocco's High Commission of Forest and Water and Combating Desertification [5.5, 5.6]). This has had a significant positive affect on soil conservation: *"We have now reduced soil loss in the Tangier-Tétouan region by 40% and by around 60% in the Casablanca-Settat region."* [5.5]. These reductions in soil loss in the Tangier-Tétouan region have been responsible for increasing the economic productivity of individual farmers, again highlighting the impact of Blake's research and training in socio-economic as well as soil conservation terms: "*Since the scientists [trained by Blake] helped me to conserve my soil, my farm has been producing 20 to 30% more with less input, and my income has gone up"* [5.6]. Much of this extra income is now going toward schooling of the farmer's four children: *"I am determined to offer them the education I could never get."* [ibid].

4.2 Pioneering change in land management practices at the community-level: northern Tanzania

While land management policy in East Africa is traditionally top-down, there has long been a history of local governance at the community level that is not necessarily formalised or entrained into state governance mechanisms. The 'Jali Ardhi' project (funded by the Global Challenges Research Fund) led by Blake tapped into this potential to bring change in land management practice, overcoming implementation gaps between policy and practice. Blake, Kelly and team applied their interdisciplinary and participatory methodology to enable a 'bottom-up' approach to changing land management practices to support soil conservation in remote Maasai communities in the degraded pastoral land of the Lake Manyara catchment of northern Tanzania [5.7]. During 2017, this team held 17 interviews and a workshop with pastoralists, farmers, community leaders, representatives from farmer organisations, and local government officials. This enabled the forensic analytical tools to be coupled with social science expertise and local community knowledge, to understand the complexity and barriers to implementation of soil conservation measures, and led to the co-design of changes to land management practices with the local community.

Through continued community engagement funded by an NERC Follow-on grant, Emaerete Village (a cornerstone study site) undertook pioneering change in land management practices. This involved: (i) new and locally enforced grazing regimes with restriction and exclusion of cattle from severely eroded and gullied communal grazing land around the village from July 2019: *"The plot has helped in managing soil erosion and water run-offs. The approach of reserving and setting out grazing areas have been used elsewhere in the village, for example, the area around where the demo plot is and in individual areas, people have respect to such places, and they have started seen differences happening at their lands".* [5.7 - Gustav Joachim, Emaerete Village Chairman]*;* (ii) strategic planting of 200 trees in December 2019 to slow down runoff in hydrologically vulnerable hot spots act and trap sediment - workshop participants from Emaerete have acknowledged that the village have already started witnessing benefits to the land after the trees were planted including prevention of further soil erosion and water run-off, with the tree-planting program have extended to individuals households too [5.7]; and (iii) the formation of a village environment committee to plan future initiatives. The success of the initial tree planting programme has led to further investment by CORDS [Community Research and Development Service], an NGO working in the region: *"…they [CORDS] came and see that the village have already started doing something about their land…they provided Emaerete with more trees and education"* [5.7 – Daniel Sokoine, Chairman Emaerete Environment Committee]. In addition, Monduli District Council wants to extend this programme to other villages in the district, as the problem of soil erosion still poses a challenge to communities in this area [5.7].

A specific workshop run by the project team in November 2019 with Monduli District Council and all 3 of the 'Jali Ardhi' project communities identified the need for, and importance of, new byelaws to improve the governance and protection of degraded and vulnerable land. As a direct result of this workshop, all 3 communities have now established a set of new bye-laws to support sustainable land use, which centre on (i) management of cattle through rotational grazing; (ii) fines for grazing cattle in reserved areas; and (iii) mandatory planting of up to 10 trees per year by each household: *"At the village level, we have established by-laws that guides management of cattle grazing and laws that foster tree planting initiatives. We have reserved areas for grazing during different seasons of the year (rotational grazing) and if found grazing on one of these reserved areas, a fine of 50,000 TZS will be placed upon. We also have laws that instructs every house/family to plant 10 trees at their residence per year"* [5.7 – Olais Tayai, Lendikinya Village Chairman].

For Monduli District Council, the overall impact of 'Jali Ardhi' is multi-faceted: *"Experiences from Jali Ardhi project has helped the district in many ways in land use plans and on sustainable land management and agricultural practices including technical education it provided on contour farming practices and the use of terraces at Emaerete and Enguiki villages to prevent soil erosion"* [5.7 – Roy Mruma, Agriculture Extension Officer, Monduli District Council].

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

5.1 Letter of Attestation, Section Head, Joint UN FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Soil and Water Management and Crop Nutrition Section, Vienna (Austria), 2020

5.2 IAEA Soils Newsletter Vol. 37, No. 2, January 2015

5.3 IAEA Soils Newsletter Vol. 39, No. 2, January 2017

5.4 IAEA Success story flyer " Viet Nam Tackles Soil Erosion With Nuclear Techniques"

5.5 Benmansour et al., 2019, Research into Practice—Linking Be-7 Evidence to Land Management Policy Change for Improved Food Security, In: Mabit and Blake (Eds*), Assessing Recent Soil Erosion Rates through the Use of Beryllium-7 (Be-7)*, 2019. Springer, ISBN 978-3-030-10982-0

5.6 IAEA Success story flyer "*How to Win a Fight Against Soil Erosion: Nuclear Science Helps Farmers in Morocco*"

5.7 Summary transcript of interviews with Village Chairman in Emaerete, Lendikinya and Arkaria, and Monduli District Council officials (October 2020).