Analyzing the implications of farmer seed recycling practices for crop improvement and biosafety

This highly interdisciplinary project builds on existing work and priorities already identified through rural research by African scientists to understand the processes of on-farm innovation through seed recycling in Kenyan maize systems. It addresses MDG goals 1 (eradication of extreme poverty and hunger) and 7 (ensuring environmental sustainability) and links closely to several of the principles and priorities outlined in DfID's 2005 policy paper "Growth and poverty reduction: the role of agriculture". Using rural socio-economic research, molecular analysis and agent-based modelling techniques, it aims to answer fundamental questions about the implications of on-farm innovation for crop improvement strategies, biosafety policy and *in situ* conservation of genetic diversity. It focuses on the case study of transgenic insect-resistant Bt maize (developed by the Insect Resistant Maize for Africa, IRMA project; Mugo *et al* 2005) and addresses the following questions:

- How do farmers incorporate new improved genetic material with existing germplasm in order to adapt it to local conditions, and what are the strategic implications for crop improvement efforts at the national and international levels?
- What are the implications of on-farm innovation for biosafety policies, specifically in the areas of co-existence and insect resistance management?
- How does the introduction of new genetic material affect the capacity of *in situ* conservation to maintain diverse and resilient crop systems?

The rise of participatory/ highly client-oriented plant breeding approaches that pay increasing attention to the local contexts in which improved germplasm will be adopted is helping to bridge innovation efforts in the laboratory with those at the farm level (Morris and Bellon 2004). On-farm innovation through selection and adaptation of improved genetic material in marginal environments enables "subjective traits" (for taste, culinary quality etc) to be maintained, avoids deskilling caused by reliance on improved varieties, promotes genetic conservation *in situ* and thus helps build diversity and resilience (Stirling and Mayer, 2000). Breakthroughs in genomics and modelling now for the first time allow these complex innovative processes to be studied at the individual genetic (as well as varietal) level. This understanding opens up a new paradigm in crop improvement that could maximise the contribution of farmer selection whilst drastically reducing the time-frames and financial resources currently required for laboratory and field research.

From molecular and socio-economic data, the project will create descriptive and predictive models of changing maize gene-pools, as influenced by social, technological and environmental factors. This will not only help inform crop improvement strategies, but also deliver vital information on the potential for coexistence of Bt maize with conventional varieties, and on appropriate strategies for Bt insect resistance management (IRM) in Kenya. Beyond the simple Bt trait, the project's molecular characterisation of local varieties also begins to build a platform upon which similar modelling techniques may be applied to more complex traits that participatory research has shown are also highly valued by farmers, such as storage pest resistance and drought tolerance.

The project builds on past collaborations between Sussex and CIMMYT Nairobi (Ely *et al* 2002) and links closely to forthcoming work funded under the new ESRC STEPS (Social, Technological and Environmental Pathways to Sustainability) centre. This linkage allows for complementary support from colleagues at the Institute for Development Studies (in particular Prof Ian Scoones) and access to a growing international research network in science and technology for development, for which the STEPS centre will provide a hub. The project involves three work-packages, co-ordinated through annual meetings (involving all partners) and periodic visits/ research stays. These are further discussed overleaf.

Project duration: 42 months from October 2007 to March 2011
Principal investigator (WP1):
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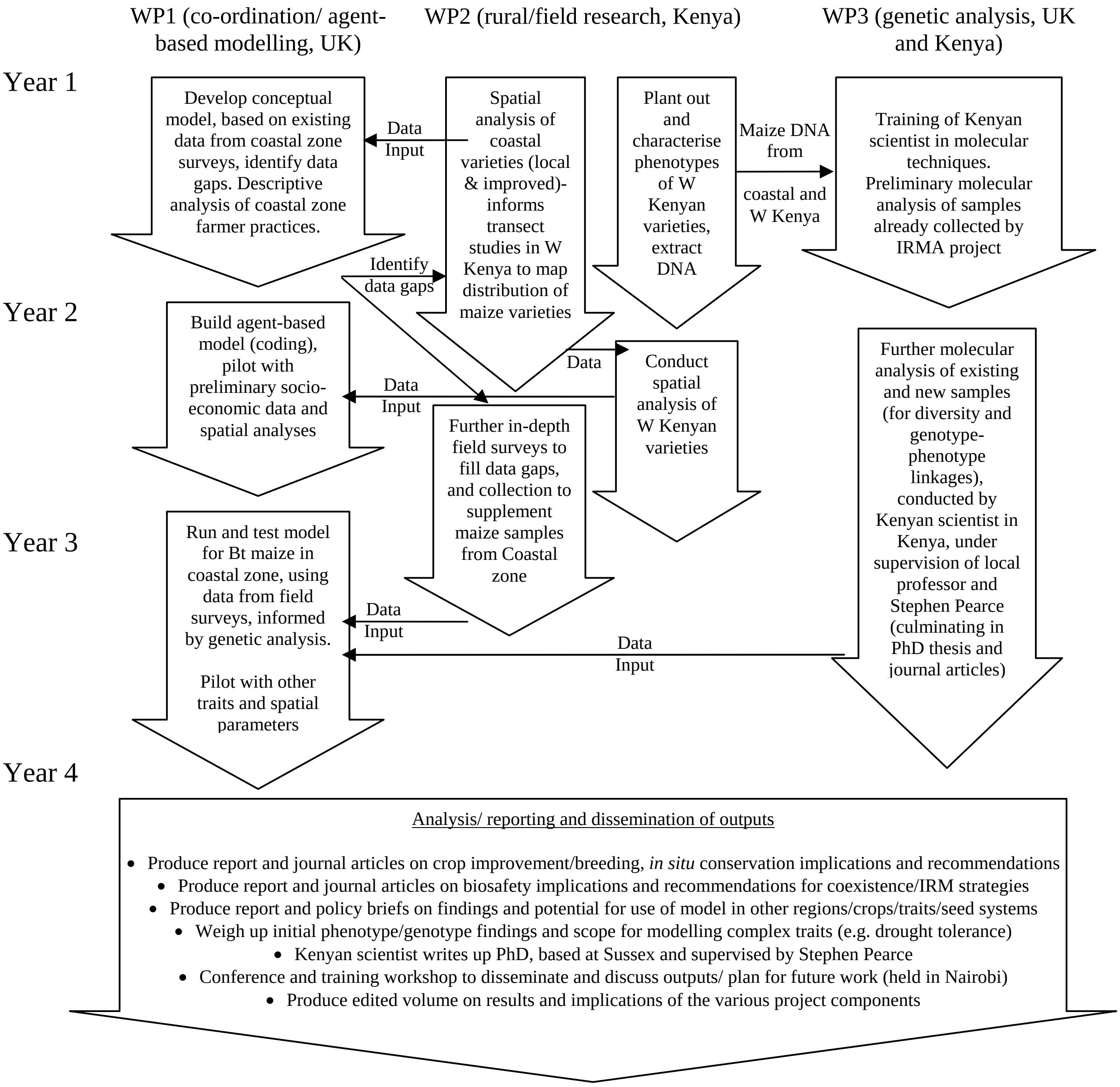
Researcher/co-investigators (WP1 and 3) not including 1 new appointment:
Dr Adrian Ely, SPRU – Science and Technology Policy Research, University of Sussex, (WP 1/ co-ordinator)
Dr Stephen Pearce, Dept of Biology and Environmental Science, University of Sussex, (WP3)
Dr Sigrid Stagl, SPRU – Science and Technology Policy Research, University of Sussex (WP1)
Overseas collaborators - Kenya (WP2) not including 2 new appointments:
Drs Hugo De Groote & Stephen Mugo, Intl Centre for Maize and Wheat Improvement (CIMMYT), Nairobi
Were Oyeho, breeder, Kenya Agricultural Research Institute (KARI), Kakamega
James B. Ndiso, Kilifi Institute of Agriculture, Kilifi

Schedule of Activities and Interactions between Work Packages



Work Package 1: Agent-based modelling of adoption and on-farm germplasm improvement

This work package will be led by Sigrid Stagl at SPRU (University of Sussex) and will employ a post-doctoral researcher. Based on a literature review and existing IRMA data, the general concepts for incorporation into a data-informed agent-based model (as used in Franks *et al* in press) will be developed. The model will analyse how different types of maize plants (heterogeneous agents) influence each other over time and how farmer behaviour changes in response to this. Initially, a theoretical model (including a learning algorithm to simulate adaptive farmer behaviour; Stagl 2007) will be designed, indicating what remaining data are required from the field. While additional data are being gathered (by WP2), the model will be coded. In year 3, the in-depth data will be used to build a predictive model for estimating the patterns of gene-flow between different types of farms (small/large early adopters, late adopters and non/inadvertent adopters; another kind of heterogeneous agents) under a variety of types of agri-environmental conditions. Spatially explicit agent-based modelling approaches (especially appropriate in a patchy, mixed cropping environment) represent a significant improvement over current Mendelian deterministic simulation models used for biosafety policy under the cultivation conditions of the USA (Grimm and Railsback 2005).

Once the model has been developed and calibrated using molecular data emerging from WP3 (see overleaf), its application in other crops and traits will be possible. An important strength of this project is the transferability of the findings to other crop species, traits, geographic regions and agri-environment scenarios.

Work Package 2: Field research on farmer practices and local varieties

This work package will be carried out in Kenya by local collaborators of the Kilifi Institute of Agriculture and the Kenya Agricultural Research Institute (KARI), Kakamega (overseen by Hugo De Groote and Stephen Mugo, with Adrian Ely providing the link to the other two work packages at Sussex). The field research on local varieties has four major components: characterization of local varieties, analysis of their spatial distribution, analysis of farmers' seed recycling practices, and livelihood analysis. The work package will first build on previous work on coastal varieties by characterising varieties from seed samples collected in Western Kenya. These varieties will be planted out for phenotypic characterization. DNA from the sampled varieties of both regions will be extracted and sent to Sussex for molecular characterization by a Kenyan scientist (WP3). WP2 will also analyse the existing data already collected by the IRMA project on the spatial distribution of the coastal varieties, informing model design in WP1. A methodology for the spatial analysis will be developed, and the results will indicate how the design of transect sampling can be improved upon. These methodologies will then be applied to collecting data on the spatial distribution of local varieties in Western Kenya. Farmers' seed recycling strategies will be analysed using IRMA's baseline data from a 2001-2 survey of 1800 farmers, containing information on seed saving, selection and exchange. The analysis will be followed up by in depth interviews with a limited number of farmers, to understand the rationale behind the practices. Group discussions will provide information on how local varieties and seed recycling affect livelihoods. The information gathered in the four components will feed into the model developed in the UK for policy application.

Work Package 3: Genetic analysis of crop samples

This work package will be led by Stephen Pearce at the University of Sussex. A Kenyan scientist will spend one year at Sussex receiving training in molecular marker analysis techniques, drawing on existing expertise in analysis of crop genetic diversity (Bousios *et al* 2006, Tam *et al* 2005) and components of the MSc in Plant Conservation (seedbanking). This period will involve supervised analysis of DNA samples provided by the IRMA project by SSR, SSAP, AFLP and retrotransposon-based marker technologies to characterise the diversity of, and phylogenetic relationships between local and improved varieties from coastal and West Kenyan, as well as food aid varieties. This data will inform the WP1 model, and add greatly to current evidence for policy-making on co-existence and IRM. This initial training will be used in years 2 and 3 when these analyses will continue in Kenya, and will culminate in the writing up of a PhD at Sussex.

The possibility also exists to investigate the extent of maize seed-saving and the introgression of transgenes into local varieties in South Africa, where commercial Bt maize has already been cultivated for several years. Whether funded by BBSRC/DfID or other donors, this would prove a useful additional component to this project (not costed below). Sussex University have already entered into discussions with potential South African partners, in particular the Council for Scientific and Industrial Research (CSIR).

Summary Estimates of fEC Costs

	WP1	WP2	WP3	Total
Directly incurred	158,859	296,239	55,136	510,234
Directly allocated	-	-	-	-
Indirect costs	161,779	-	11,157	172,936
Total	320,638	296,239	66,293	**£683,170**

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