The Role of Agroecology in Sustainable Intensification

The new study, 'The Role of Agroecology in Sustainable Intensification,' undertaken by the Organic Research Centre with the Game and Wildlife Conservation Trust, was commissioned by the inter-agency Land Use Policy Group (LUPG) and funded by Scottish Natural Heritage and Natural Resources Wales. The study found that agroecological practices and and systems, including integrated farming, organic farming and agroforestry, can help maintain agricultural productivity and enhance the environment. The authors ***Nic Lampkin, Bruce Pearce, Alastair Leake, Henry Creissen, Catherine Gerrard, Sofi Lloyd, Susanne Padel, Jo Smith, Laurence Smith, Anja Vieweger*** *and* ***Martin Wolf reviewed*** *the range of agroecological approaches and their performance, finding that there was potential for win-win situations where both productivity and the environment could be enhanced.*

Sustainable intensification and agroecology

'Sustainable intensification' is now often used to describe the future direction for agriculture and food production as a way to address the challenges of increasing global population, food security, climate change and resource conservation. While sustainable intensification is interpreted by some to relate to increasing production, with more efficient but potentially increased use of inputs and technology, there is also a need to consider environmental protection, including the conservation and renewal of natural capital and the output of ecosystem services. There is a growing consensus that sustainable intensification should not only avoid further environmental damage, but actively encourage environmental benefits. This includes addressing issues of consumption (including diets), waste, biodiversity conservation and resource use, while ensuring sufficient overall levels of production to meet human needs.

'Agroecology' is also now receiving increasing attention as an approach to agriculture that attempts to reconcile environmental, sustainability and production goals by emphasising the application of ecological concepts and principles to the design and management of agricultural systems. Agroecology can be seen as part of a broader approach to sustainable intensification focusing on ecological (or eco-functional) and knowledge intensification alongside technological intensification.

The report explores from a UK perspective how agroecological approaches can contribute to sustainable intensification by:

- exploring the concepts of 'sustainable intensification' and 'agroecology';
- reviewing the range of individual practices and systematic approaches that are typically defined as agroecological;
- assessing the extent to which different agroecological approaches can contribute to sustainability outcomes; and
- considering the policy drivers and constraints that may affect the adoption of agroecological approaches.

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Three levels of adoption of agroecology are relevant:

1. an efficiency/substitution approach focusing on alternative practices and inputs with an emphasis on functional biodiversity, or eco-functional intensification, to reduce or replace external, synthetic, non-renewable inputs;
2. a whole system redesign approach focused on the farm ecosystem;
3. a focus on agriculture as a human activity system, including the issues of labour and knowledge/skills on farm as well as interactions between producers, supply chain actors and consumers.

Agroecology can also be considered in terms of transformation of social and economic systems, but this aspect was not a focus of this report.

Nitrogen provided by clover nodules can help to reduce imports of synthetically fixed nitrogen and increase forage yields

Agroecological approaches

A wide range of agricultural practices and system components are identified in the literature as being agroecological in nature. The following list provides an illustrative overview, but is not exhaustive:

- reliance on soil biota, e.g. earthworms, for soil structure, formation of water stable aggregates, and soil water infiltration;
- biological nitrogen fixation using legumes and symbiotic N-fixing bacteria;
- the use of biologically active soil amendments (e.g. composts) to suppress soil-borne diseases;
- passive biological control of pests using field margin refugia or beetle banks to encourage presence of beneficial insects;
- temporal and spatial design of cropping systems to disrupt pest life cycles or attract pests away from sensitive crops (including push-pull systems);
- crop rotation to manage soil fertility and crop protection more generally;
- use of cultivar and species mixtures, including perennial and annual species and composite cross populations within species, to improve resource use efficiency and reduce pathogen spread between individuals with different genetic susceptibilities;
- utilisation of grassland by multiple livestock species, ensuring effective resource utilisation (different grazing behaviours) as well as health management (pathogen/parasite transfer and lifecycle patterns in pastoral ecosystems).

There are some common features within these practices:

- they have a strong biological rather than technological focus, with reliance on knowledge, skills and experience for their effective management;
- they emphasise diversity of system components and complex relations between components to deliver system resilience and stability;
- to the extent that they are used effectively, they permit reduced use of industrial/ technological/ synthetic agrochemical inputs.

Mollison (1990) describes the idea of complexity in agroecosystems as follows:

- each function (e.g. weed control) is delivered by multiple components/practices (e.g. variety selection, timing of sowing/planting, rotations etc.)
- each component/practice (e.g. green manures) has multiple functions (e.g. nutrient conservation, nitrogen fixation, soil protection etc.)

This builds on the ecological theory of niche differentiation - different species obtain resources from different parts of the environment, and the greater the number of trophic relationships (where one organism obtains resources from another), the more resilient a system is to shocks or disturbances that may impact seriously on one component. It is clear that any of these practices can be used by any farmer, but it is the use and integration of multiple practices and the possible synergies at a system level that characterises an agroecological approach to agriculture.

Recognising the potential for synergies, there have been many attempts to integrate agroecological practices and

Chicory helps reduce parasite problems in sheep

restrictions on the use of certain practices/technologies into defined agroecological approaches, ranging from integrated pest, crop and farm management through conservation agriculture, organic farming, biodynamic agriculture, eco-farming, regenerative agriculture to agroforestry, permaculture and many similar variants. Some have been better developed, codified and researched than others, and for the purposes of this study we focused on evaluating integrated crop management/conservation agriculture, organic farming and agroforestry in more detail.

The contribution of agroecological approaches to sustainability outcomes

To assess the contribution of agroecological approaches to sustainability outcomes we drew on a combination of grey and peer-reviewed literature, other web-based resources and quantitative data where available, to describe and assess the performance of agroecological systems and strategies compared with more conventional approaches to sustainable intensification.

Any assessment of performance requires the identification of relevant objectives, related outputs or indicators of performance, and criteria against which success or failure of different systems can be determined. In this context there are a very wide range of possible objectives, systems, metrics and indicators with variable data quality and comparability, so inevitably some constraint to the assessment, and reliance on judgement, is required.

Given the potential complexity of the evaluation, we have restricted the scope to five primary objectives:

i. Productivity

ii. Carbon sequestration, greenhouse gas emissions and energy use

iii. Biodiversity and related ecosystem services

iv. Soil and water resources (physical aspects)

v. Profitability

The assessment of the different agroecological practices and approaches presented in the report demonstrate that there are differences in performance with respect to each of the objectives, and that there may be both synergies and conflicts between objectives in specific cases. In Table 1 we summarise our assessment of the relative contribution of individual practices, as well as of the major approaches (integrated, organic, agroforestry) reviewed. It should be noted that in this table the scoring represents an assessment of whether the impact is better or worse than conventional intensive systems.

Table 1. Contribution of different agroecology practices and approaches to defined sustainable intensification objectives

Practice	Productivity	Non-renewable energy use and GHG emissions	Biodiversity and related ecosystem services	Soil and water resource protection	Profitability
Fertility-building legume leys	+ (- if not utilised)	+	+ (++ if flowering)	++(if well managed)	-
Organic soil amendments	+	+	++	+	0
Reduced/ zero tillage	+	+	+	+	+
Avoidance of agrochemicals	--	+	++	++	--
Extended crop rotations	+	0/+	+	+	+/-
Polycultures	++	0/+	+	+	+/-
Variety mixtures and populations	+	0/+	+	0	0/-
Field margin and other refugia	+/-	0/+	+/++	0/+	+/-
IPM/biological pest control	+	0/+	+	0	+
Diverse pastures	+	0/+	+	+	0/+
Mixed crops and livestock	+ (if complementary)	0/+	+	+	+/-
Mixed livestock species	+ (if complementary)	0/+	+	0	+/-
Integrated crop/ farm management	0	+	+	+	0/+
Organic farming	--	+ (0 per unit product)	++	++	0 (with premiums)
Agroforestry	+	++	++ (- if bare understorey)	++	+/-

- = worse than conventional, 0 = similar to conventional, + = better than conventional

Source: Own assessment based on literature presented in the full report.

From our evaluation, we concluded that agroecological perspectives may be applied to the management of soils, crops and livestock, as well as to broader societal, environmental and food system issues. Agroecological practices, such as the use of rotations and polycultures, biological pest control, or legumes to biologically fix nitrogen, are not unique to particular groups of farmers. They can be used by all farmers, individually or in combination. However, synergies between individual practices can be important. Agroecology emphasises the idea of 'system redesign' rather than 'input substitution' for maximum benefit. In some cases, as in organic farming, the combination of practices may be codified (regulated) to enable marketing of products at premium prices to consumers. A range of more or less codified, systematic approaches, ranging from integrated pest and crop management through conservation agriculture and organic farming to agroforestry and permaculture, are described in the literature.

Three of the best documented approaches – integrated crop/farm management, organic farming and agroforestry – are assessed in detail, in comparison with intensive, conventional systems, with respect to their contribution to: (i) productivity; (ii) energy use and greenhouse gas emissions; (iii) biodiversity and related ecosystem services; (iv) soil and water conservation; and (v) profitability.

Overall, our assessment is that, in general, the potential of agroecological approaches to contribute to sustainable intensification is positive. We recognise that this assessment does not account for sometimes wide performance variations in specific situations. We have also not sought to provide an overall rating combining the different objectives assessed, as the allocation of weightings to individual objectives can vary widely between different stakeholders.

In some cases the impacts could be positive or negative, depending on a) whether the practice, e.g. field margin refugia, enables more cost-savings/yield gain than the land taken out of production, and b) whether the species mixtures used (crops and/or livestock) are complementary and similarly profitable. In some cases, such as the impacts of reduced use of agrochemicals and organic farming on productivity and biodiversity, there is clear evidence of trade-offs that need to balanced. The resolution of trade-offs is a complex question, which is only starting to be explored in the sustainability literature (e.g. German et al., in review).

Despite the very wide range of studies reviewed in this report, there are still significant methodological challenges to measuring and understanding the relative performance of different practices and approaches.

This analysis concludes that agroecological approaches can:

- maintain or increase productivity, with the exception of organic farming where yields per ha may be substantially reduced due to restrictions on the use of agrochemical inputs – however organic system productivity with respect to other inputs including labour, and in terms of resource use (other than land) per unit of food produced, may be similar or better;
- contribute to reducing non-renewable energy consumption, both on a per unit of land and a per unit of product basis – although the benefits per unit of product are not as high in the organic case due to the lower yields;
- maintain or increase biodiversity and the output of related ecosystem services – with appropriately designed and managed agroforestry and organic systems offering potentially greater benefits than integrated systems;
- maintain natural capital in the form of soil and water resources as a result of reduced use, careful management (e.g. reduced or zero tillage) and reduced or restricted use of potentially polluting inputs;
- maintain or increase the profitability of farming systems through more efficient input use reducing costs, diversifying the range of outputs and, in the organic case, developing specialist markets with premium prices to help compensate for the lower yields.

The analysis further suggests that there will be both win-win situations, as in the case of agroforestry, as well as trade-offs between objectives, for example between productivity and biodiversity in the organic case. The latter might be compensated for by market mechanisms and/or policy interventions. To the extent that high outputs per unit land depend on inputs of non-renewable resources and degradation of natural capital, some compromises might be needed to deliver longer-term sustainability. This also illustrates the need for the maintenance of functional biodiversity components in productive agricultural landscapes to deliver the ecosystem services that can enable reduced use of unsustainable inputs and practices.

Overall, there is a clear case that agroecological approaches can make a substantial contribution to sustainable intensification, but this needs to be supported by an improved knowledge system (including training, education, advice and research with active farmer engagement), as well as by policy drivers, such as those adopted in the French agroecology action plan, to encourage change. There is also no one single approach that is likely to deliver all benefits simultaneously – a mosaic of approaches addressing specific needs is likely to deliver better overall results, as well as provide insurance against a single preferred strategy failing to deliver in practice.

Photo: Bob Crowder

Orchard and flowering understorey: Passive biological control of crop pests by encouraging beneficials

Cattle grazing in a silvo-pastoral system

Recommendations

- Future work on sustainable intensification should place high priority on the sustainability component of the concept, including eco-functional and knowledge intensification, environmental protection and the delivery of ecosystem services;
- The potential of agroecological approaches to contribute to sustainable intensification (used in this sense described above) should be more widely recognised and developed. Agroecology is not just an option for, but an essential component of, sustainable intensification;
- Appropriate evaluation metrics should be developed to support business and policy decision-making, both at farm and regional/landscape level and taking account of different priorities (e.g. water use) in different areas;
- Policies to mitigate the negative impacts of many agricultural inputs, including fertilisers, pesticides, anti-microbials and anti-helminthics, should emphasise agroecological approaches in addition to technological or risk management solutions (as in the EU Sustainable Use of Pesticides Directive and the French agroecology action plan);
- Agri-environmental support, payments for ecosystem services (PES) and market-based policies (e.g. product certification) should be used to encourage the adoption of a broad range of agroecological approaches;
- Improved agroecological information and knowledge exchange systems, building on tacit farmer knowledge and active producer participation, should be developed and promoted. Achieving this will require better integration and co-ordination between individuals and organisations working on the subject, as well as the collaborative development of both on-line resources and traditional extension services;
- Educational provision, whether at vocational skills, further and higher education levels or more widely, should include a stronger focus on agroecological approaches – in the short term this issue can be addressed through the provision of targeted support (using the RDP vocational skills measures) but in the longer term a wide range of educational curricula need to be reviewed and updated;
- Research and innovation policy should include more focus on the development of agroecological approaches, not just their comparative evaluation. Support policies need to facilitate participatory delivery models and address the challenges involved in securing private sector funding for applied research that generates public knowledge not linked to saleable technologies and intellectual property.

References

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