SIXTH FRAMEWORK PROGRAMME
PRIORITY 8.1
Scientific Support to Policies (SSP)

**Deliverable 4.4 Report on results of land use projections**

Project acronym: **COCONUT**

Project full title: **Understanding effects of land use changes on ecosystems to halt loss of biodiversity due to habitat destruction, fragmentation and degradation**

Proposal/Contract no.: **044346**

Date of delivery: **30th of April 2009**

Project home page: **www.coconut-project.net**

**Comment:**

Understanding effects of land-use changes on ecosystems to halt loss of biodiversity due to habitat destruction, fragmentation and degradation

Proposal/Contract no.: 044346

# D4.4. Report on results of land-use projections

Responsible partner: University of Edinburgh

Contributors: Sophie Rickebusch*, Marc Metzger, Mark Rounsevell

*contact person


## Abstract

This report presents a new, rule-based method for downscaling land-use change projections. The aim is to achieve sufficient spatial and thematic resolution for applications in ecology, such as projecting future habitat quality. The ALARM projections (10' resolution) for three future land-use scenarios were downscaled to 100 m resolution in four transects (2 x 15 km) within the UK, following a set of rules derived from the scenario storylines.

The results for these transects show distinct differences between the three scenarios, notably in terms of conversion to biofuel crop production. For some land-use categories, such as urban, the differences are not so much in the quantity than in the location of the new areas.

The downscaling approach give good results for spatially-limited areas such as our transects and includes elements of decision-making which are difficult to reproduce with statistical downscaling. It also has the potential to be used for stakeholder participation, for instance. A further development could be to automate the application of the rules, so that the method could be used for larger areas.

## Introduction

Although changes in land-use and -cover have been occurring for centuries, they have increased in the past few decades. These changes can have a considerable impact, either negative or positive, on the environment and on biodiversity. In the coming decades, radical changes in agricultural land-use can be expected (Busch 2006) and most probably also in other land-use classes, e.g. urban. One challenge facing those who try to project future land-uses is achieving sufficient spatial and thematic resolution.

The BIOPRESS project measured historic land-cover changes in 59 transects, each containing part of a Natura 2000 site, across 7 European countries, using aerial photographs from the 1950s, 1990s and 2000 (Olschofsky *et al.* 2006). It is finely resolved both spatially and thematically. Combining the results from all the transects showed a general decrease in agricultural land and an increase in artificial surfaces, forest and semi-natural areas.

Within the ALARM project (Settele *et al.* 2005), land-use change projections were developed for three core scenarios (Box 1) and three “shock” derived scenarios. The thematic and spatial resolutions are quite coarse. All three showed a continuation of trends seen in the past 50 years, such as agricultural land abandonment and increased urbanisation, but the magnitude of change differed between scenarios (Reginster *et al.* submitted).

Box 1. *Brief description of the three ALARM scenarios. Adapted from Reginster & Rounsevell (in prep.)*

**GRAS** (GRowth Applied Strategy): deregulation and free trade lead to reduction/abolition of zoning, non-application of EU planning policy guidelines, urban sprawl and diffuse peri-urbanisation; agriculture is only maintained in optimal location due to abolition of subsidies; current protected areas are preserved but NATURA 2000 network not enforced.

**BAMBU** (Business-As-Might-Be-Usual): planning policy guidelines and compact city development are enforced; agriculture is maintained in optimal locations and at low levels in traditional landscapes; current afforestation policy is maintained; current protected areas are preserved and the NATURA 2000 network enforced.

**SEDG** (Sustainable European Development Goal): integrated policies lead to extensification of agriculture and organic farming; strict planning policies favour compact settlement to reduce travel needs; current protected areas are preserved and the NATURA 2000 network enforced.

Our aim here is to provide fine-scale projections of future land-use in some BIOPRESS transects, by combining the information from the BIOPRESS historic data with the ALARM scenarios using a rule-based, qualitative approach. These projections may then be used to assess the effect of the scenarios on, for instance, habitat quality.

## Material & methods

We focused on four BIOPRESS transects situated in the United Kingdom (Table 1). These were chosen because they contain a large part of their associated Natura 2000 site(s) and are therefore most suitable for subsequent habitat quality analysis. The dimensions of all the transects are 15 x 2 km. The data was originally in polygon format, each of which contained CORINE land-cover (CLC) level 3 (44 classes) values for 1950, 1990 and 2000 (Olschofsky *et al.* 2006). The shapes of the polygons within a transect are therefore determined by the changes which have occurred. From this we created grid datasets of the three time steps at 100 x 100 m resolution for each of our focus transects. These were then transformed into point data (grid cell

Table 1. *Summary of BIOPRESS transects.*

| Code | Name | Past changes |
|---|---|---|
| UK1 | Kennet Valley Alderwoods | Increase in artificial surfaces & small increase in forest, decrease in agricultural land |
| UK2 | Hackpen Hill | Increase in artificial surfaces, decrease in agricultural land & forest |
| UK5 | Butser Hill | Increase in artificial surfaces & small increase in forest, decrease in agricultural land |
| UK8 | Sands of Forvie | Increase in artificial surfaces, decrease in agricultural land & forest |

centres). The associated attribute table contained the values for the three past time steps, plus three new fields for 2030, one per scenario, which were filled with the 2000 values as a starting point.

For each of the three scenarios (Box 1), the ALARM land-use change data gives the percentage cover of seven land-use types for 27 countries (EU25, Switzerland & Norway) on a 10 x 10' (lat/lon) grid (Reginster *et al.* submitted). The land-use types are: urban, cropland, grassland, permanent crops, biofuels, forests and land in succession (i.e. abandoned agricultural land.)

The allocation of projected land-use change from the pan-European ALARM scenarios to the more detailed CLC legend consisted of three steps. Firstly, the relative change of four aggregated land-use change categories was derived from the pan-European ALARM scenarios and converted an absolute increase or decrease in 1 ha grid cells using the transect data. Secondly, these changes were thematically disaggregated to the detailed legend, providing information about the number of 1 ha grids cells by which each land-cover category will increase or decrease under the scenario. Finally, these changes were allocated in the transect using a combination of scenario specific rules, regional information and expert judgement. Below, these three steps are described in more detail.

Quantifying land-cover changes for the transects requires insight in the relative change compared to the present situation. However, because the ALARM bio-energy and 'surplus' land categories are not present in the baseline situation, it is not possible to calculate relative change figures for these categories. To overcome this problem, the relative change was calculated for aggregated categories, which incorporate the bio-energy crops, i.e. 'total crops', 'total forest', 'grasslands' and 'built-up area' (Table 2). The relative changes derived from the ALARM scenarios were used to calculate the absolute change in 1 ha grid cells in each transect. These changes were subsequently disaggregated to the more detailed CORINE level, as described below.

Two other land-use category groups can be discerned. Firstly, the categories which are assumed to be uninfluenced by the most important land-use change drivers (Rounsevell *et al.* 2005). These include land-cover types such as bare rock, water bodies, glaciers and natural areas. Because under the ALARM scenario assumptions these do not change, they were left out of this analysis. Secondly, the 'surplus land' category, consisting mainly of abandoned agricultural land. Surplus land is defined as the remaining land after the land demand for urban use, agriculture and forestry has been met. As such, it can be calculated as the sum of all land-use changes.

Table 2. *Aggregation of ALARM and CORINE categories.*

| Aggregated category | ALARM | CORINE |
|---|---|---|
| total crops | cropland<br>permanent crops<br>liquid bio-energy crops<br>non-woody bio-energy crops | arable land (2.1)<br>heterogeneous agricultural areas (2.4)<br>permanent crop (2.2) |
| total forest | forest<br>woody bio-energy crops | forest (3.1) |
| grasslands | grasslands | pastures (2.3)<br>natural grasslands (3.2.1) |
| built-up area | built-up area | all artificial surfaces (1) |

The ALARM scenarios were constructed using the relatively coarse 1 km resolution PELCOM land-cover map, which can deviate considerably from detailed regional land-use patterns (Schmit *et al.* 2006). Consequently, there are problems when individual 10' ALARM grid cells are used to derive future change. For example, the ALARM grid cell may not contain urban area, resulting in no change, while in reality there are small settlements in the region. This problem can be overcome by calculating average trends over a wider region. Here, we chose to use the average regional trends for the principal European environmental zones, which were also used in the combined deliverable report for D4.1-D4.3 to assess the regional variability of the ALARM scenarios.

The relative proportions of bio-energy to conventional cropland or forest in the ALARM scenarios were used to disaggregate the 'total crops' and 'total forest' categories, respectively. So, if under a certain scenario the 'total forest' category increased by 50 1 ha grid cells from 1500 to 1550, while at the same time the fraction of woody bio-energy crops increased from 0% to 10%, then under that scenario conventional forestry would decrease by 105 cells to 1395 (1550 – (1550 * 10/100)) and woody bio-energy crops would increase by 155 cells. In this way, it is possible to obtain absolute changes for the three types of bio-energy crops as well as arable land, permanent crops and forests. Since some future land-use categories do not yet exist in the CORINE classification, we created a new level 2 class (2.5) for bio-energy crops, which consists of: liquid bio-bioenergy crops (2.5.1), non-woody bio-energy crops (2.5.2) and woody bio-energy crops (2.5.3). Additionally, we created two categories for surplus land (abandoned agricultural land) within the relevant level 2 groups: abandoned arable land (2.1.4) and abandoned pastures (2.3.2).

The numbers of points (grid cells) of each type in the transects were then adjusted to match the downscaled ALARM values for each scenario. This was done in ArcGIS by selecting the desired points manually and changing the corresponding field in the attribute table, using the field calculator. The changes followed the order of precedence shown in Figure 1. Details of the rules for each transect and scenario can be found in the Appendix. In general terms, protected areas

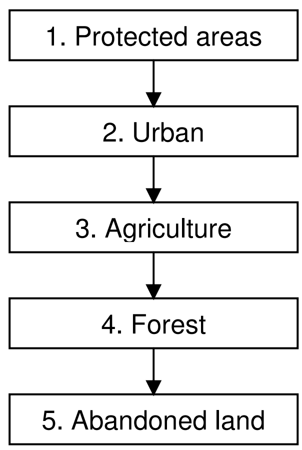


Figure 1. *Order of precedence for land-use change allocation.*

were preserved (with an additional buffer zone of 100 m for the SEDG scenario), so no changes were allowed. Urban areas expanded mostly into agricultural land-use types, with locations in accordance with the scenarios. Agricultural land tended to decrease, with some conversion to biofuels (woody biofuels could also be grown on land converted from forest) and in some cases to forest. Surplus land (mostly from agriculture) was considered to be abandoned. Cells were preferably changed in clumps corresponding to the original BIOPRESS polygons, i.e. areas which had a common history of change, because these are likely to be the result of other factors, such as land-ownership, which will also affect future changes.

Once all the changes had been made, we created grids of the projected land-use according to each of the scenarios.

## Results

Figure 2 shows an example of land-cover projections for transect UK1 (Kennet Valley

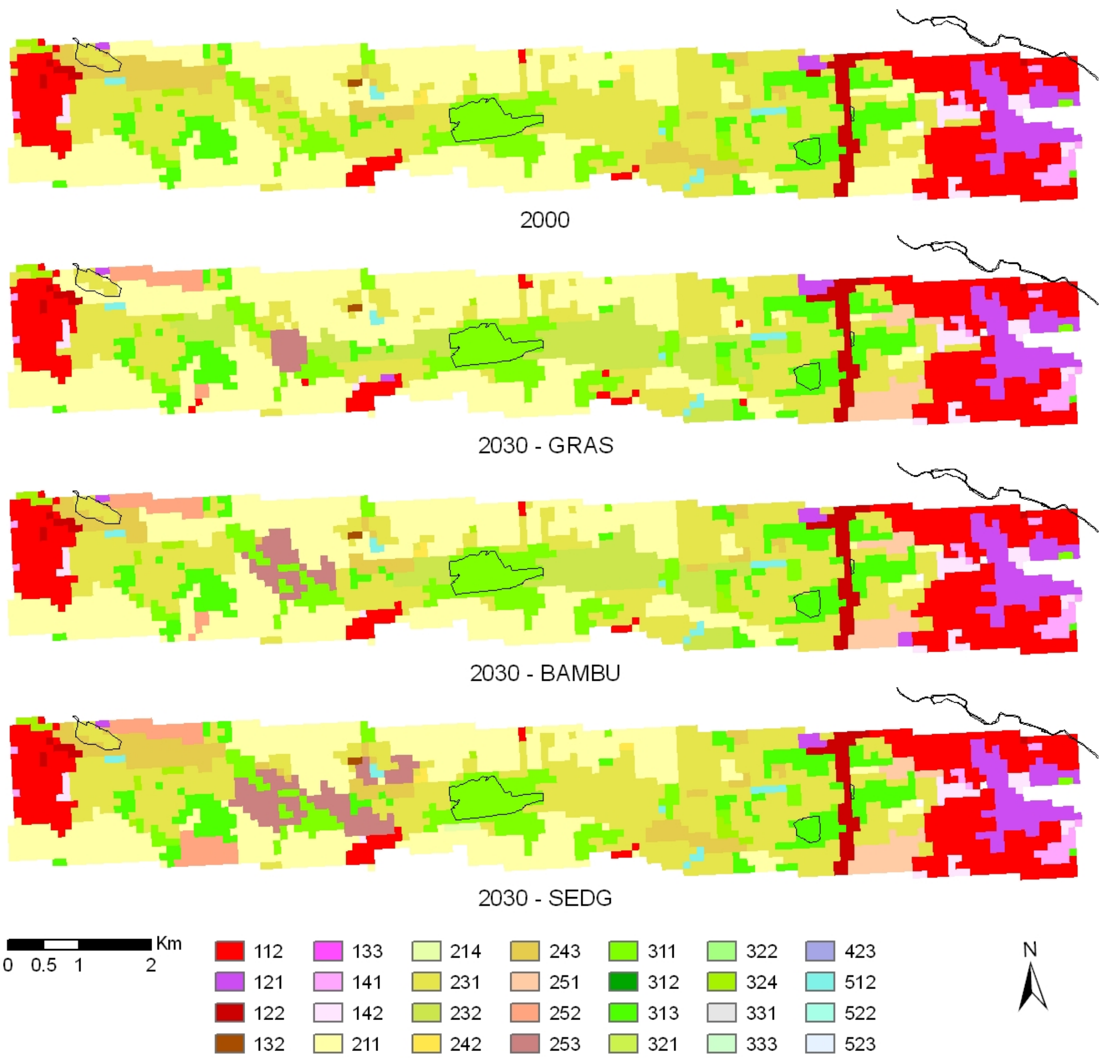


Figure 2. *Transect UK1 (Kennet Valley Alderwoods). Current (2000) land-cover and projections for 2030 according to three scenarios. The categories correspond to CORINE land-cover level 3, except for the new categories: 214 (abandoned arable land), 232 (abandoned pastures), 251 (liquid biofuels), 252 (non-woody biofuels) & 253 (woody biofuels). The black lines are the perimeters of the protected areas.*

Alderwoods) according to the three ALARM scenarios. Urban areas (categories 112-142) increase in all scenarios, but locations are scattered with GRAS, whereas with SEDG they are close to existing urban centres. The GRAS scenario has the lowest conversion to biofuel crops (251-253) and the most abandonment of pasture land (232), while the SEDG scenario is the opposite. Abandoned land is mostly situated along the Kennet River, as this was deemed more likely to be difficult of access, i.e. less profitable for agriculture. Similar maps for the other three transects can be found in the Appendix.

The evolution of the area covered by each land-use category over time (Figure 3) shows that the differences between the scenarios for urban and forests are much smaller than the changes in the past 50 years, in transect UK1. The greatest differences appear in the different categories of agricultural land (intensive, extensive and biofuels.)

## Discussion

Our example transect (UK1 - Kennet Valley Alderwoods) shows little difference between the scenarios in quantity of new urban land-use by 2030, but the locations of the new urban areas vary from scattered new settlements (GRAS) to compact city development (SEDG). The slight increase in arable land in the GRAS scenario may at first glance seem strange. However, it has to be weighed against the loss of heterogeneous agricultural areas and the relatively low uptake of biofuel production, so it is in fact a sign of intensification, not an increase in agriculture as a whole. The "pastures" category also remains fairly high in the GRAS scenario, but a lot of these

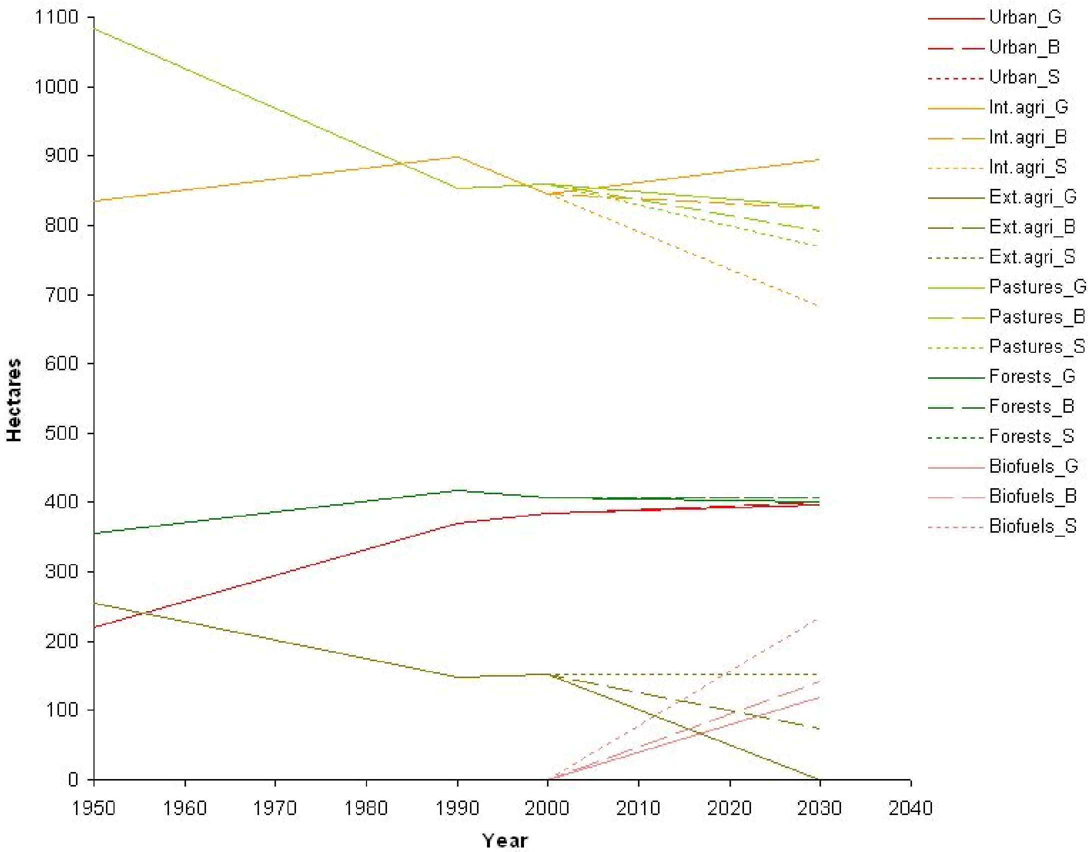


Figure 3. *Land-use change in transect UK1 between 1950 and 2030 for scenarios GRAS (full), BAMBU (dashed) and SEDG (dotted). The categories correspond to CLC level 2: 1.1 (urban), 2.1 (arable), 2.4 (heterogeneous agricultural), 2.3 (pastures), 3.1 (forests) and the new category 2.5 (biofuels).*

are surplus or abandoned pastures. Some of the remainder may be linked to leisure activities, such as grazing for horses.

The high uptake of biofuel production in the SEDG scenario raises an interesting paradox in terms of natural habitat quality. Although this scenario is supposedly the most “sustainable”, biofuel monocultures may not be very good wildlife habitats. On the other hand, the large quantities of abandoned agricultural land and pastures in the GRAS scenario may actually improve the overall habitat quality in the area.

Although downscaling of land-use change projections has been done in the past, it is generally limited in spatial and thematic resolution. For instance, Verburg *et al.* (2008; 2006) have projected land-use change for the whole of Europe, but at a spatial resolution of 250-1000 m and with fewer than 10 land-use categories. This is insufficient for many uses in ecology, such as habitat quality assessment, which require a finer output, e.g. distinguishing between types of forest rather that forest vs. urban land. However, using a finer thematic resolution will exacerbate the discrepancies in the original data from different time steps or countries (e.g. CORINE vs. PELCOM), which are masked when the land-uses are grouped into broader categories. The downscaling and allocation method described here on the other hand gives good results when a finer resolution is necessary.

This method has some other advantages. First of all, it incorporates an element of more or less arbitrary decision-making. This mimics local decision-making by planners, farmers and other agents, such as switching from food to biofuel crop production, which is only partly driven by market rules. It is therefore much more flexible than statistical downscaling and allocation, which cannot take into account some essentially human aspects of decision-making. Another interesting side to this method is the possibility of using it for a participatory approach by asking stakeholders to choose the location of land-use changes.

The main disadvantage of this method is its limited spatial extent, as it would not be practical or efficient to select and change manually more than one to a few hundred points. However, it may be possible to automate the rule base to obtain results for larger areas. This would still be a more flexible approach than pure statistical downscaling.

The new method for projecting land-use change which we described here shows distinct advantages in terms of spatial and thematic resolution, as well as the ability to give more life-like results. It also opens some interesting possibilities as a tool for stakeholder dialogue.

## References

Busch G. (2006) Future European agricultural landscapes - What can we learn from existing quantitative land use scenario studies? *Agriculture Ecosystems & Environment* 114: 121-140.

Olschofsky K., Köhler R. & Gerard F. eds. (2006) *Land cover change in Europe from the 1950'ies to 2000*. World Forestry, Hamburg.

Reginster I. & Rounsevell M. (in prep.) Environmental pressures arising from scenarios of European land use change.

Reginster I., Rounsevell M., Riguelle F., Carter T. R., Fronzek S., Oman I., Spangenberg J. H., Stocker A., Bondeau A. & Hickler T. (submitted) The effects of alternative socio-economic and environmental policies on European land use from 2006 to 2080. *Land Use Policy*.

Rounsevell M. D. A., Ewert F., Reginster I., Leemans R. & Carter T. R. (2005) Future scenarios of European agricultural land use II. Projecting changes in cropland and grassland. *Agriculture Ecosystems & Environment* 107: 117-135.

Schmit C., Rounsevell M. D. A. & La Jeunesse I. (2006) The limitations of spatial land use data in environmental analysis. *Environmental Science & Policy* 9: 174-188.

Settele J., Hammen V., Hulme P., Karlson U., Klotz S., Kotarac M., Kunin W., Marion G., O'Connor M., Petanidou T., Peterson K., Potts S., Pritchard H., Pysek P., Rounsevell M., Spangenberg J., Steffan-Dewenter I., Sykes M., Vighi M., Zobel M. & Kuhn I. (2005) ALARM: Assessing LArge-scale environmental Risks for biodiversity with tested Methods. *Gaia-Ecological Perspectives for Science and Society* 14: 69-72.

Verburg P. H., Eickhout B. & van Meijl H. (2008) A multi-scale, multi-model approach for analyzing the future dynamics of European land use. *Annals of Regional Science* 42: 57-77.

Verburg P. H., Schulp C. J. E., Witte N. & Veldkamp A. (2006) Downscaling of land use change scenarios to assess the dynamics of European landscapes. *Agriculture Ecosystems & Environment* 114: 39-56.

## Appendix

### *UK1 - Kennet Valley Alderwoods*

Aggregated changes derived form the ALARM scenarios for the Central Atlantic zone.

| **Change 2000 - 2030** | | | |
|---|---|---|---|
| | BAMBU | GRAS | SEDG |
| urban | 1.04 | 1.05 | 1.04 |
| arable | 0.99 | 0.99 | 0.95 |
| grass | 0.70 | 0.64 | 0.89 |
| forest | 1.13 | 1.05 | 1.27 |

Disaggregated land cover data based on detailed land cover data in the transect. Numbers indicate the change in 1ha grid cells.

| | | **BAMBU** | **GRAS** | **SEDG** |
|---|---|---|---|---|
| | | **urban** | | |
| 112 | 63% | 16 | 17 | 16 |
| 121 | 18% | 4 | 5 | 4 |
| 122 | 9% | 2 | 2 | 2 |
| 132 | 0% | 0 | 0 | 0 |
| 141 | 4% | 1 | 1 | 1 |
| 142 | 6% | 1 | 2 | 1 |
| | | **arable** | | |
| arable | | -97 | -107 | -174 |
| liquid bf | | 50 | 59 | 58 |
| nw biofules | | 36 | 34 | 63 |
| | | **grassland** | | |
| grassland | | -251 | -302 | -91 |
| | | **forest** | | |
| forest | | 1 | -7 | 1 |
| woody-biofuels | | 55 | 27 | 114 |
| | | **other** | | |
| surplus | | 180 | 269 | 4 |

Land-cover allocation rules and decisions (*italics*) for the three ALARM scenarios (GRAS, BAMBU & SEDG.) The result is shown in Figure 2.

| | **GRAS** | ***Comments*** |
|---|---|---|
| **1. Protected areas** | Current protected areas maintained | |
| **2. Urban** | Dispersed urban sprawl, new urban centres can appear | |
| | *Distribute ALARM change according to current distribution of CLC types, allocate urban growth* | *Small new settlements, some expansion of small existing town Existing industrial sites expand, new site near small town* |

| | | |
|---|---|---|
| **3. Agriculture** | Agriculture shifts to most favourable areas | |
| | *Estimate best locations. First allocate crops, then bio-energy crops, then grassland. Less intensive agriculture categories disappear first* | *Arable that was grassland before, in block with some grassland*<br>*Large single patch of forest in agricultural matrix* |
| **4. Forest** | General support for afforestation | |
| | *Existing patches expand or contract around the periphery* | *Some conversion of woodland to woody bioenergy crops. In addition expansion of bioenergy crops on wet grasslands and arable land along river* |
| **5. Abandoned land** | Abandoned land goes into succession | *Mainly abandoned grasslands along the river, which is too wet or remote and around nature reserve* |

| | **BAMBU** | ***Comments*** |
|---|---|---|
| **1. Protected areas** | Current protected areas maintained | |
| **2. Urban** | Compact city development and peri-urbanisation around existing smaller centres | |
| | *Distribute ALARM change according to current distribution of CLC types, allocate urban growth* | *Urban expansion on agricultural land around existing towns. New industrial sites located on edge of towns. Bypass extended to industrial estate. Urban green in arable field in town. New leisure facility next to village* |
| **3. Agriculture** | Limited shifts in agriculture to most favourable areas | |
| | *Estimate best locations. First allocate crops, then bio-energy crops, then grassland. Less intensive agriculture categories reduce by 50%* | *Liquid biofuels located on arable land near towns/ industry* |
| **4. Forest** | General support for afforestation | |
| | *Existing patches expand or contract around the periphery* | *Expansion of small patches. Woody biofuels located on grasslands and arable land along river* |
| **5. Abandoned land** | Abandoned land goes into succession | *Mainly abandoned grasslands along the river, which is too wet or remote* |

| | SEDG | *Comments* |
|---|---|---|
| **1. Protected areas** | Current protected areas maintained | |
| | *Expand protection with 100m buffer* | |
| **2. Urban** | Compact city development and peri-urbanisation around existing cities | |
| | *Distribute ALARM change according to current distribution of CLC types, allocate urban growth* | *Urban expansion on agricultural land around existing towns. New industrial sites located on edge of towns. Bypass extended to industrial estate. Urban green in arable field in town. New leisure facility next to village* |
| **3. Agriculture** | Extensification - little change in agriculture distribution | |
| | *Estimate best locations. First allocate crops, then bio-energy crops, then grassland. Less intensive agriculture categories are maintained* | *Liquid biofuels located on arable land near towns/ industry* |
| **4. Forest** | General support for afforestation | |
| | *Existing patches expand or contract around the periphery* | *Expansion of small patches. Woody biofuels located on grasslands and arable land along river* |
| **5. Abandoned land** | Abandoned land goes into succession | *Very limited abandonment of grasslands along the river* |

*UK2 - Hackpen Hill*

Aggregated changes derived form the ALARM scenarios for the Central Atlantic zone.

| Change 2000 - 2030 | BAMBU | GRAS | SEDG |
|---|---|---|---|
| urban | 1.04 | 1.05 | 1.04 |
| arable | 0.99 | 0.99 | 0.95 |
| grass | 0.70 | 0.64 | 0.89 |
| forest | 1.13 | 1.05 | 1.27 |

Disaggregated land cover data based on detailed land cover data in the transect. Numbers indicate the change in 1ha grid cells.

| | | BAMBU | GRAS | SEDG |
|---|---|---|---|---|
| | | **urban** | | |
| 112 | 68.58% | 12 | 13 | 12 |
| 121 | 16.35% | 3 | 3 | 3 |
| 122 | 0.76% | 0 | 0 | 0 |
| 131 | 1.38% | 0 | 0 | 0 |
| 133 | 0.32% | 0 | 0 | 0 |
| 141 | 1.74% | 0 | 0 | 0 |
| 142 | 10.87% | 2 | 2 | 2 |
| | | **arable** | | |
| arable | | -163 | -180 | -293 |
| liquid bf | | 85 | 99 | 98 |
| nw biofules | | 61 | 57 | 107 |
| | | **grassland** | | |
| grassland | | -157 | -189 | -57 |
| | | **forest** | | |
| forest | | 0 | 1 | 0 |
| woody-biofuels | | 6 | 3 | 12 |
| **surplus** | | 151 | 190 | 116 |

Land-cover allocation rules and decisions (*italics*) for the three ALARM scenarios (GRAS, BAMBU & SEDG.) The result is shown in Figure 4.

| | GRAS | *Comments* |
|---|---|---|
| **1. Protected areas** | Current protected areas maintained | |
| **2. Urban** | Dispersed urban sprawl, new urban centres can appear | |
| | *Distribute ALARM change according to current distribution of CLC types, allocate urban growth* | *Small new settlement near Wantage, and expansion of the small hamlet outside Wantage Expand existing industrial estates. New leisure on outskirts of Wantage* |

| | | |
|---|---|---|
| **3. Agriculture** | Agriculture shifts to most favourable areas | |
| | *Estimate best locations. First allocate crops, then bio-energy crops, then grassland. Less intensive agriculture categories disappear first* | *Bio-energy crops are lumped together and allocated to large, flat arable land parcels* |
| **4. Forest** | General support for afforestation | |
| | *Existing patches expand or contract around the periphery* | *Woody biofuels lumped near industry, on former arable*<br>*Mixed forest expansion of existing woodland* |
| **5. Abandoned land** | Abandoned land goes into succession | *Arable abandonment mainly on the small patches on the hill*<br>*Grassland abandonment mainly on the hill and furthest away form settlements and farms* |

| | **BAMBU** | ***Comments*** |
|---|---|---|
| **1. Protected areas** | Current protected areas maintained | |
| **2. Urban** | Compact city development and peri-urbanisation around existing smaller centres | |
| | *Distribute ALARM change according to current distribution of CLC types, allocate urban growth* | *Small towns merged, existing industrial estates expanded, new leisure facilities on edge of towns* |
| **3. Agriculture** | Limited shifts in agriculture to most favourable areas | |
| | *Estimate best locations. First allocate crops, then bio-energy crops, then grassland. Less intensive agriculture categories reduce by 50%* | *Bio-energy crops are lumped together and allocated to large, flat arable land parcels* |
| **4. Forest** | General support for afforestation | |
| | *Existing patches expand or contract around the periphery* | *Woody bioefuels lumped near industry, on former arable land*<br>*Mixed forest expansion of existing woodland* |
| **5. Abandoned land** | Abandoned land goes into succession | *Arable abandonment mainly on the small patches on the hill*<br>*Grassland abandonment mainly on the hill and furthest away form settlements and farms* |

| | SEDG | *Comments* |
|---|---|---|
| **1. Protected areas** | Current protected areas maintained | |
| | *Expand protection with 100m buffer* | *No land cover change around protected areas* |
| **2. Urban** | Compact city development and peri-urbanisation around existing cities | |
| | *Distribute ALARM change according to current distribution of CLC types, allocate urban growth* | *Small towns merged, existing industrial estates expanded, new leisure facilities on edge of towns* |
| **3. Agriculture** | Extensification - little change in agriculture distribution | |
| | *Less intensive agriculture categories are maintained. Estimate best locations. First allocate crops, then bio-energy crops, then grassland* | *Bio-energy crops are lumped together and allocated to large, flat arable land parcels, but not on land principally occupied by agriculture with significant natural vegetation* |
| **4. Forest** | General support for afforestation | |
| | *Existing patches expand or contract around the periphery* | *Woody bioefuels lumped near industry, on former arable land* |
| **5. Abandoned land** | Abandoned land goes into succession | *Arable abandonment mainly on the small patches on the hill Grassland abandonment mainly on the hill and furthest away form settlements and farms* |

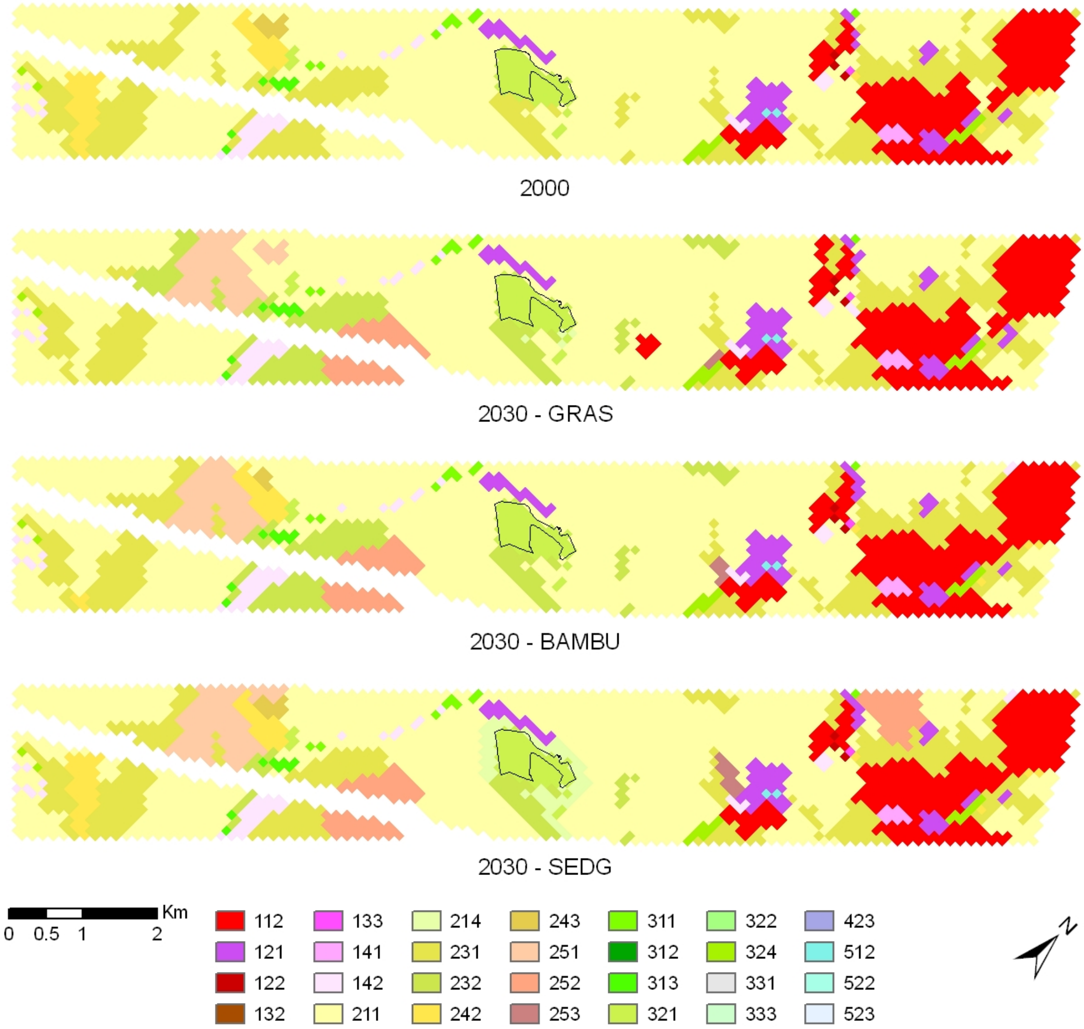


Figure 4. *Transect UK2 (Hackpen Hill). Current (2000) land-cover and projections for 2030 according to three scenarios. The categories correspond to CORINE land-cover level 3, except for the new categories: 214 (abandoned arable land), 232 (abandoned pastures), 251 (liquid biofuels), 252 (non-woody biofuels) & 253 (woody biofuels). The black lines are the perimeters of the protected areas.*

*UK5 - Butser Hill*

Aggregated changes derived form the ALARM scenarios for the Central Atlantic zone.

| **Change 2000 - 2030** | BAMBU | GRAS | SEDG |
|---|---|---|---|
| urban | 1.04 | 1.05 | 1.04 |
| arable | 0.99 | 0.99 | 0.95 |
| grass | 0.70 | 0.64 | 0.89 |
| forest | 1.13 | 1.05 | 1.27 |

Disaggregated land cover data based on detailed land cover data in the transect. Numbers indicate the change in 1ha grid cells.

| | | **BAMBU** | **GRAS** | **SEDG** |
|---|---|---|---|---|
| | | **urban** | | |
| 112 | 80.25% | 27 | 29 | 27 |
| 121 | 5.81% | 2 | 2 | 2 |
| 122 | 11.16% | 4 | 4 | 4 |
| 131 | 0.82% | 0 | 0 | 0 |
| 133 | 0.27% | 0 | 0 | 0 |
| 141 | 1.69% | 1 | 1 | 1 |
| 142 | 2.39% | 1 | 1 | 1 |
| | | **arable** | | |
| arable | | -68 | -75 | -123 |
| liquid bf | | 35 | 42 | 41 |
| nw biofules | | 25 | 24 | 45 |
| | | **grassland** | | |
| grassland | | -314 | -378 | -114 |
| | | **forest** | | |
| forest | | 1 | -8 | 1 |
| woody-biofuels | | 57 | 28 | 118 |
| | | **other** | | |
| surplus | | 229 | 331 | -3 |

Land-cover allocation rules and decisions (*italics*) for the three ALARM scenarios (GRAS, BAMBU & SEDG.) The result is shown in Figure 5.

| | **GRAS** | ***Comments*** |
|---|---|---|
| **1. Protected areas** | Current protected areas maintained | |
| **2. Urban** | Dispersed urban sprawl, new urban centres can appear | |
| | *Distribute ALARM change according to current distribution of CLC types, allocate urban growth* | *Expansion of existing centres as well as the emergence of new settlement near larger towns* |
| **3. Agriculture** | Agriculture shifts to most favourable areas | |
| | *Estimate best locations. First allocate crops, then bio-energy crops, then grassland. Less intensive agriculture categories disappear first* | *Biofuels as BAMBU, but slight expansion* |
| **4. Forest** | General support for afforestation | |
| | *Existing patches expand or contract around the periphery* | |
| **5. Abandoned land** | Abandoned land goes into succession | |

| | **BAMBU** | ***Comments*** |
|---|---|---|
| **1. Protected areas** | Current protected areas maintained | |
| **2. Urban** | Compact city development and peri-urbanisation around existing smaller centres | |
| | *Distribute ALARM change according to current distribution of CLC types, allocate urban growth* | *Urban expansion is concentrated around the larger towns. Existing commercial sites and roads are expanded* |
| **3. Agriculture** | Limited shifts in agriculture to most favourable areas | |
| | *Estimate best locations. First allocate crops, then bio-energy crops, then grassland. Less intensive agriculture categories reduce by 50%* | |
| **4. Forest** | General support for afforestation | |
| | *Existing patches expand or contract around the periphery* | *Woody biofuels on slopes of hill (less suitable for regular crops)* |
| **5. Abandoned land** | Abandoned land goes into succession | |

| | SEDG | *Comments* |
|---|---|---|
| **1. Protected areas** | Current protected areas maintained | |
| | *Expand protection with 100 m buffer* | |
| **2. Urban** | Compact city development and peri-urbanisation around existing cities | |
| | *Distribute ALARM change according to current distribution of CLC types, allocate urban growth* | *Urban expansion is concentrated around the larger towns. Existing commercial sites and roads are expanded* |
| **3. Agriculture** | Extensification - little change in agriculture distribution | |
| | *Less intensive agriculture categories are maintained. Estimate best locations. First allocate crops, then bio-energy crops, then grassland* | |
| **4. Forest** | General support for afforestation | |
| | *Existing patches expand or contract around the periphery* | |
| **5. Abandoned land** | Abandoned land goes into succession | |

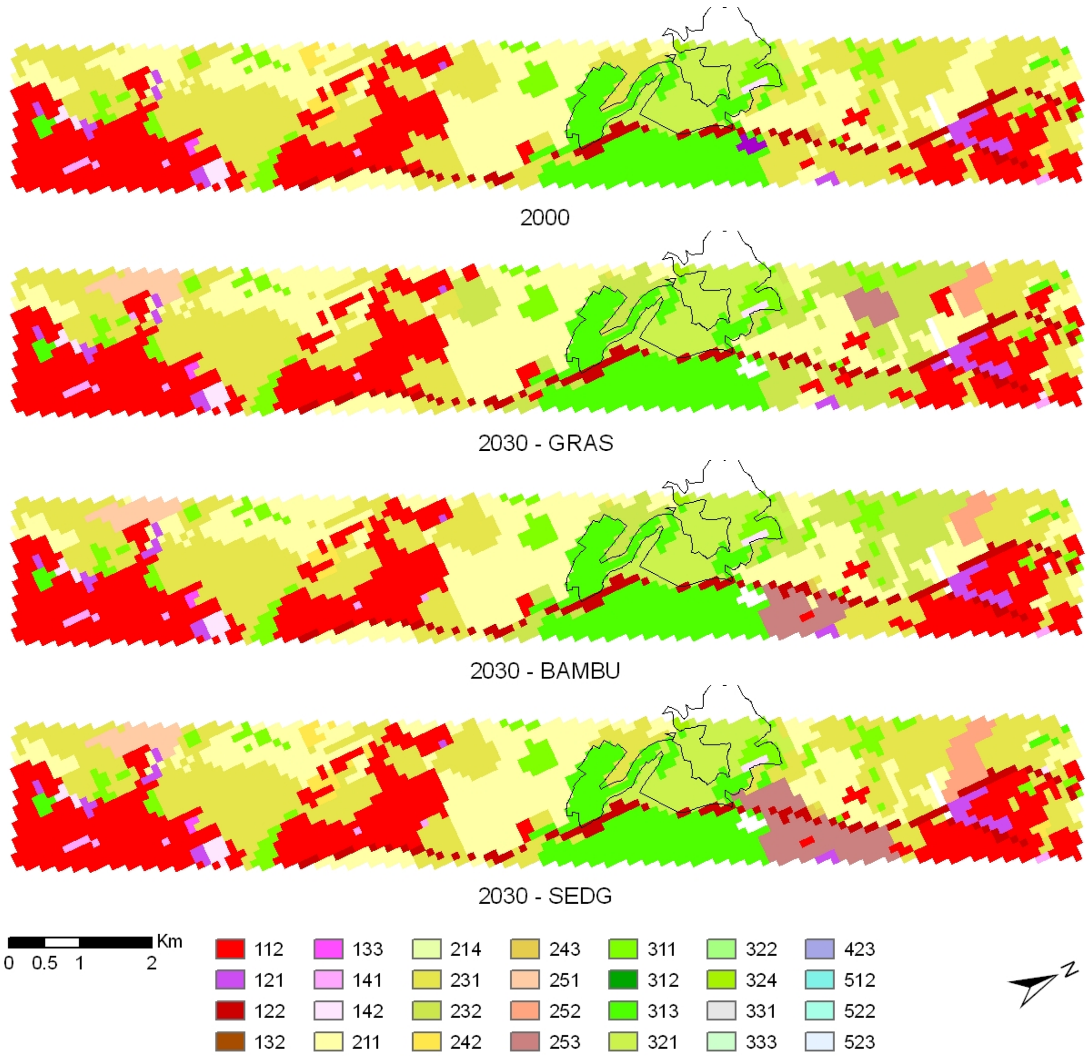


Figure 5. *Transect UK5 (Butser Hill). Current (2000) land-cover and projections for 2030 according to three scenarios. The categories correspond to CORINE land-cover level 3, except for the new categories: 214 (abandoned arable land), 232 (abandoned pastures), 251 (liquid biofuels), 252 (non-woody biofuels) & 253 (woody biofuels). The black lines are the perimeters of the protected areas.*

*UK8 - Sands of Forvie*

Aggregated changes derived form the ALARM scenarios for the Central North zone

| **Change 2000 - 2030** | BAMBU | GRAS | SEDG |
|---|---|---|---|
| urban | 1.03 | 1.04 | 1.04 |
| arable | 0.99 | 0.98 | 0.96 |
| grass | 0.87 | 0.85 | 0.90 |
| forest | 1.10 | 1.04 | 1.21 |

Disaggregated land cover data based on detailed land cover data in the transect. Numbers indicate the change in 1ha grid cells.

| | | **BAMBU** | **GRAS** | **SEDG** |
|---|---|---|---|---|
| | | **urban** | | |
| 112 | 29% | 2 | 2 | 2 |
| 122 | 5% | 0 | 0 | 0 |
| 133 | 4% | 0 | 0 | 0 |
| 141 | 2% | 0 | 0 | 0 |
| 142 | 59% | 4 | 4 | 4 |
| | | **arable** | | |
| arable | | -21 | -24 | -34 |
| liquid bf | | 11 | 12 | 12 |
| nw biofules | | 8 | 7 | 13 |
| | | **grassland** | | |
| grassland | | -93 | -109 | -70 |
| | | **forest** | | |
| forest | | -1 | -1 | -2 |
| woody-biofuels | | 5 | 2 | 10 |
| | | **other** | | |
| surplus | | 86 | 105 | 63 |

The following tables give the land-cover allocation rules and decisions (*italics*) for the three ALARM scenarios (GRAS, BAMBU & SEDG.) The result is shown in Figure 6.

| | **GRAS** | ***Comments*** |
|---|---|---|
| **1. Protected areas** | Current protected areas maintained | |
| **2. Urban** | Dispersed urban sprawl, new urban centres can appear | |
| | *Distribute ALARM change according to current distribution of CLC types, allocate urban growth* | *New urban settlement near golf course and beach, expansion of golf course* |
| **3. Agriculture** | Agriculture shifts to most favourable areas | |
| | *Less intensive agriculture categories are maintained. Estimate best locations. First allocate crops, then bio-energy crops, then grassland* | *Bio-energy on arable near town Woody bio-energy near town on remaining available arable and a forest cell* |
| **4. Forest** | General support for afforestation | |
| | *Existing patches expand or contract around the periphery.* | |
| **5. Abandoned land** | Abandoned land goes into succession | |

| | **BAMBU** | ***Comments*** |
|---|---|---|
| **1. Protected areas** | Current protected areas maintained | |
| **2. Urban** | Compact city development and peri-urbanisation around existing smaller centres | |
| | *Distribute ALARM change according to current distribution of CLC typess, allocate urban growth* | *Compact expansion around existing larger village and leisure facility* |
| **3. Agriculture** | Limited shifts in agriculture to most favourable areas | |
| | *Estimate best locations. First allocate crops, then bio-energy crops, then grassland. Less intensive agriculture categories reduce by 50%* | *Bio-energy on arable near town Woody bio-energy near town on remaining available arable and a forest cell* |
| **4. Forest** | General support for afforestation | |
| | *Existing patches expand or contract around the periphery* | |
| **5. Abandoned land** | Abandoned land goes into succession | *Grassland abandonment furthest from town and nearer to coast* |

| | SEDG | ***Comments*** |
|---|---|---|
| **1. Protected areas** | Current protected areas maintained | |
| | *Expand protection with 100 m buffer* | |
| **2. Urban** | Compact city development and peri-urbanisation around existing cities | |
| | *Distribute ALARM change according to current distribution of CLC types, allocate urban growth* | *Compact expansion around existing larger village and leisure facility* |
| **3. Agriculture** | Extensification - little change in agriculture distribution | |
| | *Estimate best locations. First allocate crops, then bio-energy crops, then grassland. Less intensive agriculture categories are maintained* | |
| **4. Forest** | General support for afforestation | |
| | *Existing patches expand or contract around the periphery* | |
| **5. Abandoned land** | Abandoned land goes into succession | Abandonment around the nature reserve and small patches around river |

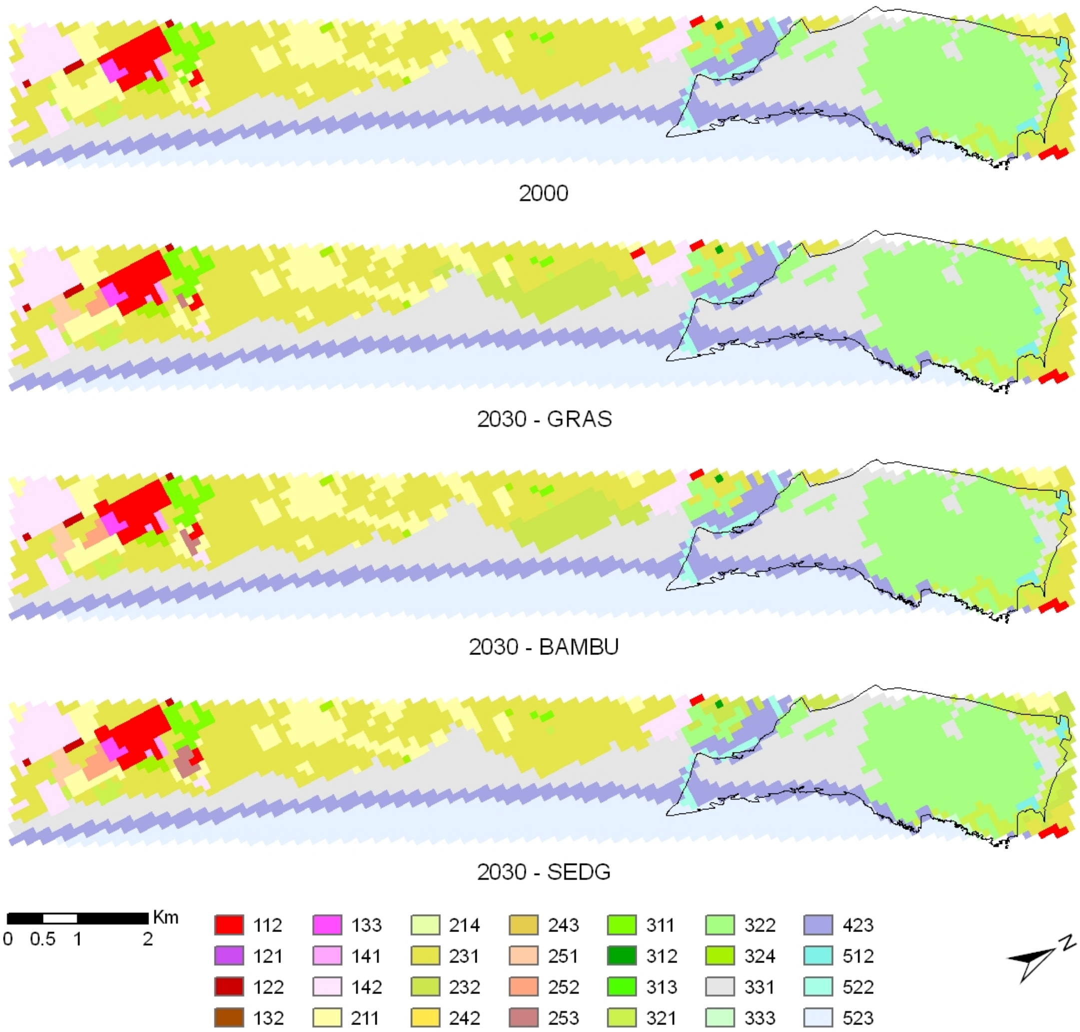


Figure 6. *Transect UK8 (Sands of Forvie). Current (2000) land-cover and projections for 2030 according to three scenarios. The categories correspond to CORINE land-cover level 3, except for the new categories: 214 (abandoned arable land), 232 (abandoned pastures), 251 (liquid biofuels), 252 (non-woody biofuels) & 253 (woody biofuels). The black lines are the perimeters of the protected areas.*