Aspects of Applied Biology **100**, 2010
Agri-environment schemes - what have they achieved and where do we go from here?

An internet-accessible tool for drawing up tailor made management plans for meadow birds

By D MELMAN[1], A SCHOTMAN[1], B VANMEULEBROUK[1], M KIERS[1], H MEEUWSEN[1], O ROOSENSCHOON[1] and G DE SNOO[2]

[1]*ALTERRA-Wageningen UR, Centre for Ecosystem Studies PO Box 47, NL-6700 AA Wageningen, The Netherlands*
[2]*Wageningen University, Centre for Ecosystem Studies, PO Box 47, NL-6700 AA Wageningen, The Netherlands*

Summary

Effective management for nature conservation needs a basis in scientific research and a careful communication of knowledge to the workers in the field. This is especially the case in agri-environmental schemes, where nature conservation is to be combined with agricultural exploitation. The assumption is that a so-called mosaic management is a good starting point, delivering chick land (land suitable for chicks) during the breeding season in the right time and place. To draw up such a plan appears to be rather complex. We developed an internet-accessible tool which can be used by farmers and agricultural nature conservations groups to enhance the quality of the management plan.

The users have to import data concerning the intended management (agri-environmental scheme as well as the regular conduct of business) and distribution of territories of an entire area. These data are used to evaluate the plan, yielding figures about the sufficiency (quality and quantity) of chick land. These figures indicate the sustainability of the population for the intended numbers and density.

In 2008 more than 50 areas (ranging from 500–1500 ha) used the knowledge system. Some evaluation results are presented. In addition feedback was obtained from the users. An important aspect is that users should not feel that the tool is a control instrument by the government. This can be achieved by giving them the choice to use the system, e.g. as a device to persuade the government about the quality of the management plan. Using the system increased the enthusiasm to work with it and gave us inspiration to further improve the system.

Key words: Management plans for meadow birds, nature conservation, chick land

Introduction

The grassland in the Netherlands forms a vital part of the habitat of meadow birds, of which the black-tailed godwit (*Limosa limosa*, see Fig. 1) is a so called flagship species. Protection of the black-tailed godwit is an important element of Dutch nature policy. A large portion of the European population is breeding in the Netherlands (*c.* 60–80% according to Hagemeijer *et al.*, 1997), but numbers are declining rapidly since black-tailed godwits cannot keep up with changes in the management of grassland to optimise yield for the farmers (MNP 2006; SOVON, 2002;

Teunissen & Soldaat 2005, Noordwijk *et al.*, 2008). The problem resulting from the intensification of the regular agricultural management is the diminishing opportunity for the black-tailed godwit to breed and raise chicks. This is due to the fact that nests are trampled by cattle or damaged while mowing, the availability of food (insects) has diminished and predation of offspring has increased (Kleijn *et al.*, 2009; Teunissen *et al*., 2005; Beintema *et al*., 1995). The availability of enough so called good quality chick land seems to be the bottle-neck for the black tailed godwit (Zwarts *et al*., 2009). Besides management, the lowering of the water table has in general a negative impact for meadow birds (Kleijn *et al.*, 2009; Berendse), decreasing the number of earthworms within reach for the adult birds (Oosterveld, 2006; Schekkerman & Boele, 2009). In fact, the grassland habitat is losing quality as a meadow bird habitat. The pieces under nature management are apparently thought to be patches of sufficient quality to enable a meadow bird population. In fact the grassland habitat is fragmented in itself. This kind of habitat fragmentation within grassland is never taken into account in the more general studies about habitat fragmentation (See e.g. Jiguet, 2004; Pouwels *et al*, 2002).

In the Netherlands, both nature conservation bodies as well as farmers, each housing substantial numbers of meadow birds, are involved with management schemes. For the farmers the agri-environmental scheme is an important vehicle. The farmers, more and more united in agricultural nature conservation groups (Oerlemans *et al*., 2004), draw up management plans to manage their meadows in a mode which is thought to be beneficial for the several meadow bird species and which fits in with the regular conduct of business. This approach, in combination with the nature reserves, should stop the decline in numbers of the black-tailed godwit, amongst other species, but have not been very effective up till now (Kleijn *et al*., 2003; Breeuwer *et al*., *2010*). A reason for this lack of success could be, that the proposed management plans do not take into consideration the temporal and spatial relations and coherency between the measures taken, thus evaluating whether the good quality grassland is too fragmented or not (Melman *et al*., 2008; Schotman *et al*., 2005; Schekkerman *et al*., 2008).

Fig. 1. Black-tailed godwit with chicks (photo by Danny Ellinger)

Spatial planning proves to be a rather complex process. It is difficult to integrate the temporal and spatial dynamics of grassland exploitation as performed in the small scaled Dutch landscape. It was decided to investigate whether an internet GIS-based knowledge system could be developed to evaluate the quality of management schemes and in addition, to support the agricultural nature conservation groups in defining the optimal management scheme for black-tailed godwits.

Materials and Methods

The system consists of two parts: (1) the ecological part; information/knowledge about the ecological conditions for black tailed godwits, especially chicks; (2) the ICT-part; an online GIS which can be used to handle and analyse spatial data regarding meadow birds (management measures and presence of meadow birds).

Ecological part of the system

Until now the system has been confined to the black tailed godwit. The ecological information needed especially concerns the breeding season (chick phase). The information looked for dealt with: (1) the foraging quality of the grassland (amount of insects and shelter) as indicated by the vegetation type and structure and state of crop; (2) the distance a family can bridge per day to assess whether a family can reach good quality chick-land. Relevant literature was scanned for information and workshops were organised with professionals to help derive reasonable assumptions where knowledge gaps existed. This resulted in tables describing the foraging quality for different grassland vegetations and state of crop as occurring in the eight single weeks of the breeding season. The state of the grassland at the time of the scan is characterized by means of 18 different crop states. The crop states determine the suitability of a parcel for the black-tailed godwit. This suitability is expressed as a factor which determines the weight of certain crop when determining the amount of actual available chick grassland, ranging from 0.0 to1.4 (Nijland, 2008).

Each management regime can be described by a series of these crop states, apparent during the breeding season. Based on the management regimes, default crop states are assigned to the parcels. If needed, these crop states can manually be adjusted, for instance when spring starts later than anticipated, which was the case in 2009 in the Netherlands. Due to a much colder winter, spring was one and a half months later than the previous year 2008 (Anon., 2009). The management regimes cover as well the regimes as taken up in the national agri-environmental scheme as the regular conduct of business practices (Schotman *et al.,* 2008).

As a base layer for the system a national map was drawn up reflecting the suitability for the black tailed godwit: the appropriateness of the abiotic conditions, i.e. landscape, water table and absence of disturbance, scale 1:10.000 (Schotman *et al*., 2007; Melman *et al*., in prep.). This map shows whether or not an area or parcel is suitable as a breeding place and makes sense to manage for meadow birds.

The way this ecological information is used to perform analyses is explained below, after introduction of the ICT-part of the system.

ICT-part of the system

This ICT-part of the system consists of a number of components. Fig. 2 gives an overview how the different components relate to each other.

Representatives of the agricultural nature conservation groups are allowed to log in to an internet GIS application (Fig. 1). This data entry application was based on a framework for web based internet GIS applications, dubbed Luigi (Vanmeulebrouk *et al*., 2008). This framework is based on Open Standards as defined by the Open Geospatial Consortium. The OGC standards applied in this particular application are the Web Map Service (WMS) standard, which produces maps with geo-referenced data (Open Geospatial Consortium Inc., 2004) and the Transactional Web Feature Service (WFS-T), standard which provides clients with read-write access to spatial data (Open Geospatial Consortium Inc., 2005).

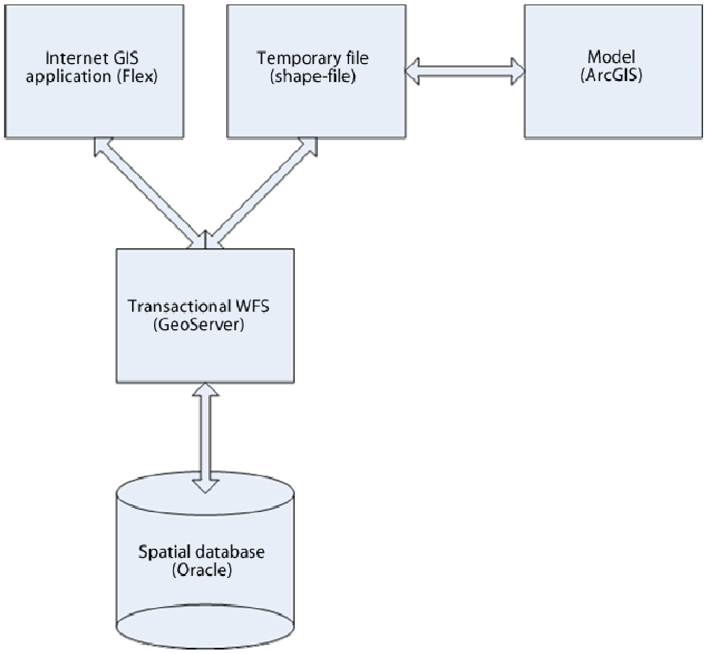

Fig. 2. Components of the system (Vanmeulebrouk, 2008).

This application can be used to enter management regimes for all parcels individually, from different owners. The management regime chosen determines the appearance of the crops (crop state) during the breeding season and accordingly, how this influences the success for the black-tailed godwit in raising their chicks. Data on the distribution of black-tailed godwit territories can be entered as well.

The available management regimes and crop states within the application are being managed by means of configuration files. These configuration files follow the Styled Layer Description specification. The OpenGIS® Styled Layer Descriptor (SLD) profile of the Web Map Service

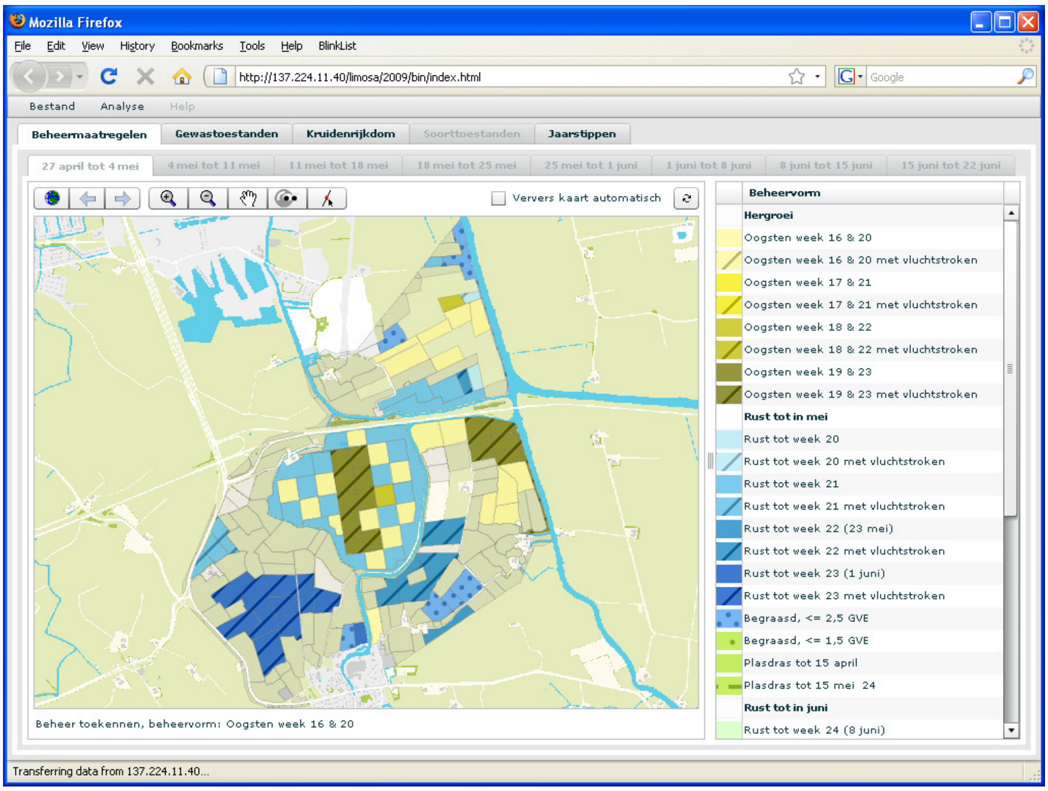

Fig. 3. Internet GIS application for entering management schemes.

Implementation Specification defines an encoding that extends the Web Map Service specification to allow user-defined symbolization of feature and coverage data. It allows users to determine which features or layers are rendered with which colors or symbols (Open Geospatial Consortium Inc., 2007). The SLD's for the input application (Fig. 3) include the Code, Description and Symbol for management scheme or crop state.

The data on management regime and distribution of the meadow birds entered using the internet GIS application are used as input for an ArcGIS model. Using this model, the quality of the management plan in terms of the sufficiency of quality/quantity of chick land is assessed. This information can be used to optimize the management plan, i.e. to adapt location and extension of the different management regimes. Focus in this model is to analyse whether the chicks are provided with grassland vegetation which supplies shelter and food at the right time and place. These qualities depend on management regime and landscape features. The model produces maps which show where and when there is a shortage or a surplus of such land. In case of a shortage or a surplus, agricultural nature conservation groups may decide to adjust their management regimes accordingly.

Since the black-tailed godwit breeding season lasts 8 weeks, this model has to be run several times thus analysing the dynamic pattern of appearance of the grassland vegetation. At the present time one analysis per week has been chosen (after experiencing that one analysis every fortnight yields too rough an insight), resulting in eight analyses for the whole season. Thus, for each week in the black-tailed godwit breeding season, the available amount of grassland suitable for raising chicks is divided over the number of black-tailed godwits present.

As has been stated in the previous paragraph, the model calculates the amount of chick grassland for black-tailed godwit. It is too simple to presume that the available area can be divided by the number of birds. The model needs the number of families which is actually present in a specific area as a parameter. A family is characterized by a nest or a territory. The number of territories which actually produce chicks differ in the season. It starts with a few territories, increases to a certain maximum and declines again (Fig. 4). In the formula below this is presented as the fraction of territories with chicks.

The next parameter which is essential is the daily spatial range of the chicks. Schekkerman *et al*. (1998) researched this topic and their figures are used in the model. If the chicks are young, they can bridge smaller distances than when they are older. This influences the amount of surrounding a which is included in the calculations to assess the available chick land.

A third parameter is the chance of survival of the chicks. If many chicks die, this leads to more available chick-grassland for the remaining families or chicks. With these parameters, the model can calculate the amount of suitable and reachable chick grassland. The simplified formula is:

available chick grassland = (area chick grassland within range / number of territories with a claim on the available area) / fraction of territories with chicks

It has been shown as plausible that this formula is sufficient in case the black-tailed godwits are able to share the available chick grassland (Schekkerman *et al*., 1998, Schotman *et al*., 2008). But in case there are isolated birds that do not have chicks, it does mean that the available land can not be used by other birds because there aren't any. The formula should be adjusted to correct for this:

available chick grassland = (area chick grassland within range / number of territories with a claim on the available area) / (fraction of territories with chicks + (1 – fraction of territories with chicks) /Number of territories which have to share chick grassland)

The following figures give an example. Given management regimes resulting in 6 ha of chick grassland in a certain week, and that 50 % of the breeding pairs have chicks and that there are 1, 5 or 10 black-tailed godwit families, the following amount of chick grassland is available:

- 1 family: (6/1) /(0.5 + 0.4/1) = 6,67 ha per family
- 5 families: (6/5)/(0.5 + 0.4/5 = 2.07 ha per family
- 10 families: (6/10) / (0.5 + 0.4/10) = 1.11 ha per family

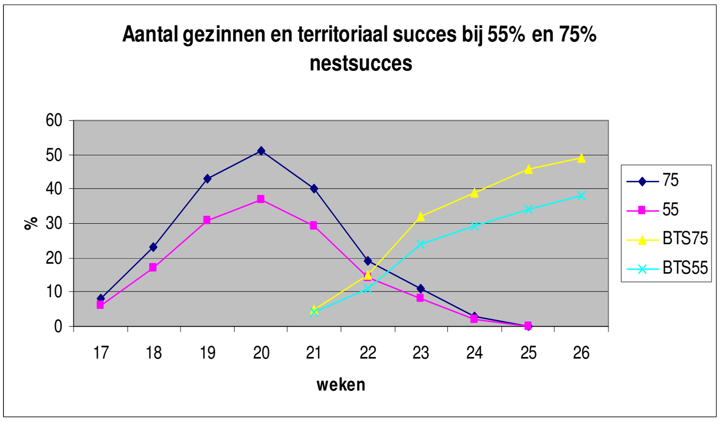

Fig. 4. Number of families present in the field during the breeding season at two nest-success percentages (dark blue and violet). Note that the highest level is 50% (at 75% success). The yellow and turquoise line represent the resulting the bruto territorial success.

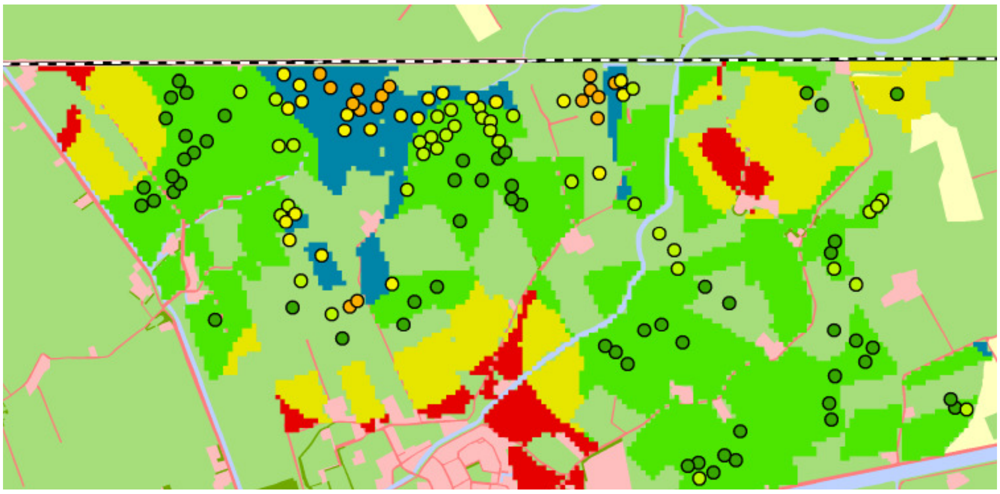

Fig. 5 provides an example of the output of the model.

Based on professional judgement it is assumed that a black-tailed godwit family needs 1.4 ha of chick land. So, in the third, most crowded situation it is expected that some families don't have enough chick land, because the average value is below 1.4.

Fig. 5 provides an example output of the model. The dots indicate black-tailed godwit territories. The coloured field indicate whether there is sufficient a shortage or surplus of chick land.

All output of the model is stored in an ArcGIS geodatabase. All relevant information is displayed in a single map. Apart from the model result displayed on a map, an overview with all relevant settings used in the model is presented.

In 2008, the system has been used for 55 nature conservation groups (Melman *et al*., 2009). For Alterra, the purpose was to test if the system works in daily practice and to obtain insight in the strengths and weaknesses. This insight can be used to further develop the system. The purpose of the agricultural nature conservation groups was to obtain an insight into the quality of the management scheme and if necessary to adjust it. This analysis was run before the black-tailed godwit breeding season. After the breeding season, the system was used to evaluate the anagement scheme again in order to compare planning and realization.

Results and Discussion

Ecological aspects

The evaluation of the areas resulted in maps and diagrams as shown in Figs 6a and 6b. The area shown is a grassland polder of about 1000 ha, south of Amsterdam. In total 233 pairs of black-

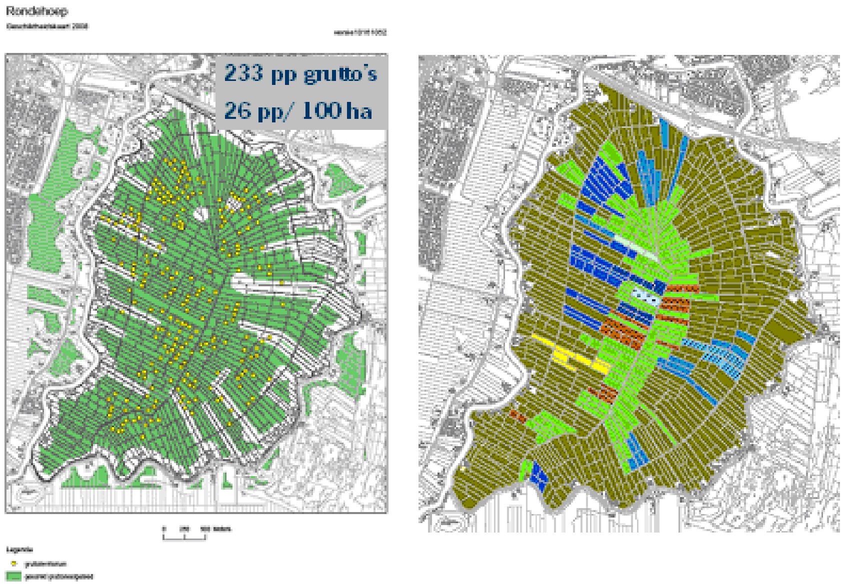

Fig. 6a. Example of an area which was evaluated. Left: the area which is assumed to be suitable for breeding (green) and the yellow dots representing the black tailed godwit territories. Right: the area managed for meadowbirds (light green, red and blue) and the area onder regular conduct of business (dark green).

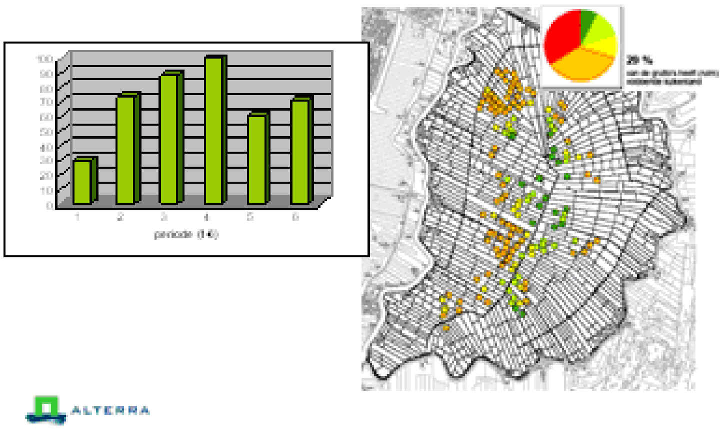

Fig. 6b. The evaluation of the management. The histogram shows the amount of chick land during the season. For meaning of the dot colours see fig. 5. The pie-diagram shows the portion of the territories with sufficient (green-yellow) and insufficient (orange-red) chick land.

tailed godwit are breeding. Almost the whole area is indicated to be suitable for breeding, except the borders (buildings, traffic) and the zone along agricultural roads penetrating the polder (Fig. 6a left). Especially the inner zone of the area is managed for meadow birds (a combination of nature reserve and agri-environmental management). The outer zone is under regular conduct of business.

For 6 weeks the area of chick land is shown (Fig. 6b). It appears that the area rises during the season but suddenly decreases in the 5th week (18–25 May). This is because mowing is at its peak during this week. On the whole the models predicts that 29% of the families produces fledgelings. For a sustainable population 50% is assumed as minimum (Schekkerman *et al*., 2008). So, according to the knowledge system the management plan should be improved. The model produces figures for evaluation, but to know the fidelity and precision of these figure validation is needed. A thorough validation is rather laborious, because you need data about the number and distribution of families and their chicks during each week of the breeding season and the state of crop at these moments for the entire area. These data are seldom gathered, but in the future we hope to get them at our disposal. In advance of such data we explored some relations.

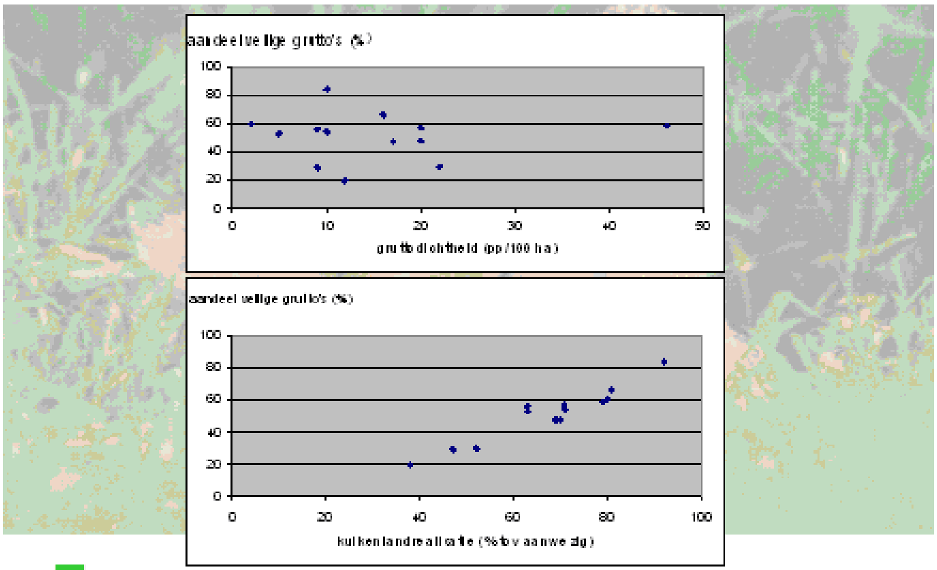

Fig. 7. Results of several areas. Above: relation between density of black-tailed godwit in an area and fraction of territories with sufficient chick land. Under: the realised chick land (related to the area needed) with the fraction of territories having sufficient chick land.

One may expect that in areas with high densities a greater proportion of the black tailed godwits have sufficient chick land than areas with low densities. However, there appears to be no such relation (Fig. 7 above). Plotting the proportion of realized chick land (related to the area needed to provide all families), with the fraction of territories with sufficient chick land results in a linear curve (Fig. 7 under). This indicates that the efficiency of the management plans in all areas is roughly the same.

Feed back from users

Practice has shown that the overall data entry takes approximately 3–4 h per area (*c.* 500–1500 ha). Most users were not experienced and worked with the system for the first time. It can be expected that more experienced users are able to enter a management scheme and territories of black-tailed godwits in two hours or less. It turned out that after users were introduced with the system, the entry of black-tailed godwit data was fairly simple.

Even before the system was tested, it was anticipated that users would judge the system a being a tool which made it possible for policymakers to control the behaviour or choices of the users, more then being a tool to assist the users. Therefore we were not surprised or disappointed when this was exactly how people reacted. Again unsurprisingly, this was even more so in cases where local policymakers had made it mandatory to use the tool in order to be eligible for subsidies.

Nevertheless, the tool received positive feedback from many agricultural nature conservation groups in the sense that the tool produced useful results, which helped them to ameliorate the management plan.

One nice remark was made by a user, a remark which may be related with a more often heard complaint that models do not reflect what really goes on.

> *"In the beginning we thought, here are those guys from Alterra again. We need to do some additional work again and we are already much occupied. But in the end, usinghis model opened our eyes. We thought that the model produced negativeresults, too negative even, because we had convinced many farmers to participate in a good quality management plan. But actual bird counts made clear that the actual situation was even more negative than predicted by the model. It became crystal clear that the situation was much less positive than we always thought it was. "*

Users of the system gave us a considerable amount of feedback, which will enable the further development of the system. Some of the remarks were related to the model and the way the results were presented, other remarks were very specific on small details or on the other hand, very general.

To name a few of them:

- Possibility of data storage. The current version can only work for the current year. Management schemes from earlier years cannot be loaded into the system automatically, nor is it possible to store different concurrent management schemes for the same year. It should also be made possible to store black-tailed godwit distribution data for more consecutive seasons.
- Possibility to use the system for other species to test the effectiveness of specific management decisions for those species.
- Possibility for the users to load their own data with black-tailed godwit appearances into the system to avoid multiple data entry.
- More freedom to make evaluate adjustments during the season.

These remarks, amongst others, are valuable material to get more insight in how users work with the system, how they rate it and where it could be improved. The remarks can be seen as additional user-requirements and will be included in further developments of the system. But like everything, it is all about priorities. It is certainly not sufficient to only deal with additional user-requirements on an ad-hoc basis. We need something more structured. Therefore we envisage that we should install a user-platform which will help us in defining priorities.

A model like the one described in this paper helps to bridge the gap between scientists and workers in the field on how an effective management scheme should be designed.

References

Anon. 2009. http://www.natuurkalender.nl/nieuwsitems/2009–03_ jaaroverzicht2008.asp.

Beintema A, Moedt O, Ellinger D. 1995. *Ecologische atlas van de Nederlandse weidevogels* (Ecological atlas of Dutch Meadow birds). Schuyt & Co, Haarlem. [in Dutch].

Breeuwer A, Berendse F, Willems F, Foppen R, Teunissen W, Schekkerman H, Goedhart P. 2009. Do meadow birds profit from agri-environment schemes in Dutch agricultural landscapes? *Biological Conservation* **142**:2949–2953.

Hagemeijer W W J M, Blair M J, Van Turnhout C, Bekhuis J, Bijlsma R. 1997. *EBCC Atlas of European Breeding Birds: their Distribution and Abundance*. London, UK: Poyser.

Jiguet F, Julliard R, Couvet D, Petiau A. 2004. Modelling spatial trends in estimated species richness using breeding bird survey data: a valuable tool in biodiversity assessment. *Biodiversity and Conservation* **14**(13):3305–3324.

Kleijn D, Sutherland W J. 2003. How effective are European agri-environment schemes in conserving and promoting biodiversity? *The Journal of Applied Ecology* **40**(6): 947–969.

Kleijn D, Dimmers W, van Kats R, Melman D. 2009. *De realtie tussen gebruiksintensiteit en de kwaliteit van graslanden als foerageerhabitat voor gruttokuikens*. Alterra-rapport 1753. Alterra, Wageningen. [in Dutch]:Alterra.

Kleijn D, Dimmers W, van Kats R, Melman Th C P. 2009. Het belang van hoog waterpeil en bemesting voor de grutto: I. de vestigingsfase. *De Levende Natuur* **110**:180–183.

Melman Th C P, Kiers M, Meeuwsen H A M, Schotman A G M, Sierdsema H, Vanmeulebrouk B, Wiersma P. 2009. *Werkzaamheden weidevogelonderzoek BO-2008; Voortgangsrapportage Beheer-op-maat* 2008; Naar identificatie kerngebieden weidevogelbeheer. Alterra-rapport 1865 (in prep).

Melman T C P, Schotman A G M, Hunink S, Snoo G R. 2008. Evaluation of meadow bird management, especially black-tailed godwit (*Limosa limosa* L.), in the Netherlands. *Journal for Nature Conservation* **16**:(2)88–95.

Melman T C P, Schotman A G M, Kiers M, de Snoo G R. 2010. Area selection for protection of meadow birds in heavily/multiple claimed/used regions (in prep.).

MNP. 2006. *Natuurbalans 2006* (Nature balance 2006). http://www.rivm.nl/bibliotheek/rapporten/500402003.pdf). Netherlands Environmental Asssessment Agency, (MNP), Bilthoven. [in Dutch, English summ.]

Nijland F. 2008. *Kuikenland, onderzoek naar gebruik van mozaïeken door steltlopergezinnen in drie gruttokringen in Fryslân in 2005–2007*. Eindrapportage Innovatieve Monitoring deel 2. Weidevogelmeetnet Friesland, publicatie Bureau N nr. 31.

van Noordwijk A J, Thompson D L. 2008. Survival rates of Black-tailed Godwits *Limosa limosa* breeding in The Netherlands estimated from ring recoveries. *Ardea* **96**:47–57.

Oerlemans N, van Well E, Guldemond J A. 2004. *Agrarische natuurverenigingen aan de slag*. Een tweede verkenning naar de rol van agrarische natuurverenigingen in natuurbeheer. Achtergronddocument bij Natuurbalans 2004. 2004/10 Natuurplanbureau. Wageningen

Oosterveld E B. 2006. Betekenis van waterpeil en bemesting voor weidevogels. *DLN* **107**(3): 134–137.

Opdam P, Foppen R, Reijnen R, Schotman A. 1995. The landscape ecological approach in bird conservation: Integrating the metapopulation concept into spatial planning. *Ibis* **137**(Suppl. 1):139–146.

Open Geospatial Consortium Inc. 2004. *OpenGIS® Web Map Server Implementation Specification*, viewed 2008–08–07, http://www.opengeospatial.org/standards/wms.

Open Geospatial Consortium Inc. 2005. *Web Feature Service Implementation Specification*, viewed 2008–08–05, http://www.opengeospatial.org/standards/wfs.

Open Geospatial Consortium Inc. 2007. *Styled Layer Descriptor*, http://www.opengeospatial.org/standards/sld.

Pouwels R, Jochem R, Reijnen M J S M, Hensen S R, van der Greft J G M. 2002. *LARCH voor ruimtelijk ecologische beoordelingen van landschappen*. Alterra rapport nr. 492. 112 pp.

Schekkerman H, Teunissen W A, Müskens G J D M. 1998. *Terreingebruik, mobiliteit en metingen van broedsucces van Grutto's in de jongenperiode*. IBN-rapport 403, SOVON-onderzoeksrapport 1998/12, DLG-publicatie 105.

Schekkerman H, Teunissen W, Oosterveld E. 2008. *Can 'mosaic management' improve breeding success and halt the population decline of Black-tailed Godwits in farmland? Precocial problems*. Alterra scientific contributions 24. Alterra, Wageningen the Netherlands.

Schekkerman H, BoeleA. 2009. Foraging in precocial chicks of the black-tailed godwit *Limosa limosa*: vulnerability to weather and prey size. *Journal of Avian Biology* **40**:369–379.

Schotman A G M, Melman Th C P, Meeuwsen H A M, Kiers M A, Kuipers H. 2005. *Naar een Grutto-mozaïekmodel; Definitie van een model voor evaluatie vooraf van de effectiviteit van mozaïekbeheer.* Stand van zaken juni 2005. Alterra rapport nr. 1199. 57 pp.

Schotman A G M, Kiers M A, Melman T C P. 2007. *Onderbouwing grutto-geschiktheidskaart Nederland; ten behoeve van grutto-mozaïekmodel en identificatie van weidevogelgebieden in Nederland*. Alterra-rapport 1407. Alterra Wageningen, the Netherlands

Schotman A G M, Melman Th C P, Hensen S R, Kiers M A, Meeuwsen H A M, Roosenschoon O R, Vanmeulebrouk B. 2008. *Het Grutto-mozaïekmodel als kwaliteittoets weidevogelbeheer; ontwikkelingen en toepassingen 2004–2008*, Alterra rapport nr. 1408. 64 pp.

SOVON. 2002. *Atlas van de Nederlandse broedvogels 1998–2000*. (*Atlas of Dutch breeding birds 1998–2000*). Nationaal Natuurhistorisch Museum Naturalis, Leiden, the Netherlands. (see also: http://www.grutto.nl/content.aspx?cid=65) [in Dutch] Eds W Teunissen, and L Soldaat (2005). Indexen en trends van een aantal weidevogelsoorten uit het weidevogelmeetnet. Periode 1990–2004 (Indices and trends of some meadow bird species of the Dutch monitoring network on meadow birds 1990–2004). SOVON Vogelonderzoek Nederland. [in Dutch].

Teunissen W A, Schekkerman H, Willems F. 2005. *Predatie bij weidevogels. Opzoek naar de mogelijke effecten van predatie op de weidevogelstand*. SOVON-onderzoeksrapport 2005/11. SOVON Vogelonderzoek Nederland, Beek-Ubbergen. Alterra-document 1292. Alterra, Wageningen. [in Dutch].

Vanmeulebrouk B, Melman D, Roosenschoon O, Schotman A, Meeuwsen H, Kiers M. 2008. Application of open source and proprietary software to optimise meadow bird management schemes in the Netherlands. *FOSS4G Proceedings*, pp. 325–33.

Zwarts L, Bijlsma R G, van der Kamp J, Wymenga E. 2009. *Living on the edge: Wetlands and birds in a changing Sahel*. Zeist, the Netherlands: KNNV Publishing.