3.2.3 LMTool

Introduction

Scope of prototype

The problem considered by the 'Landmanagement Tool' (LMTool) is for now the management of winter cover crops. However, the tool is supposed to provide general useful weather information for decision making for farmers (users have also indicated lots of potential additional uses e.g. planning cattle feed etc.) in the future. The major purpose of planting cover crops is to prevent the loss of soil and nutrients due to erosional processes. But also help to manage issues related to carbon storage, weeds, pests, diseases, biodiversity and wildlife. Thus, the application of cover or winter crops approaches a plurality of problems which are more or less climate sensitive.

Scope of vulnerability analysis

The focus of the vulnerability assessment with respect to the provision of appropriate climate information will be linked to the primary purpose of the LMTool: this is the management of winter cover crops and especially in the context of soil erosion and the erosion of newly planted crops. Thus, the discussion of this specific management problem is only one part of the scope of the prototype.

System of concern

Clinton Devon Estate (CDE) is a major regional land owner in the South West UK, with responsibility for 25,000 acres of land. Its areas of business cover farming, sustainable forestry, conservation management, deer management, commercial and residential property and businesses including the region's premier equestrian venue. CDE's decision making depends critically on land and weather conditions, covering timescales from hours to decades.

Practical cover crop management occurs on the *field scale* by the farmer as decision maker. The farmer is also in the focus of the LMTool which targets to enhance farmers decision making. The farm-system can therefore be considered as system of concern, at which the farm grounds delineate the spatial and operative boarders of this system. Success criteria for the decision-making are finally financial benefits due to a more effective workflow and economic use of resources. The workflow of winter cover crops management involves several decisions which tangent and thus affect other management decisions introducing a great deal of complexity into this system. Three basic decisions for crop management can be identified:

1. Whether to plant a winter cover crop
2. Which cover crop to choose & when to plant the crop
3. How to manage the cover crop (e.g. timing of grazing, harvesting)

Critical situations

The identification of the critical situations in this chapter is aligned to DMP's of land management which are accompanied by climate induced hazards. This is in contrast to other case-studies where DMP's are aligned to specific hazards in terms of coping.

Decision on planting cover crops

The basic decision of field planning regarding cover crops is, whether they should be planted or not. Cover crops are desired when there is a risk of soil erosion and nutrient leaching due to very wet conditions during the winter months (Perrott and Baughen 2015). This decision may become redundant when political regulations control crop rotation patterns and mixtures (Stevens 2015).

Hazard: The scope of this decision from a physical perspective is to mitigate long-term consequences of soil and nutrient loss. On the long-term the loss of soil will detract the basis to grow crops. Time scales over which impacts on crop yields will become apparent tend to be in the order of hundreds of years (Boardman 2013). However, tolerable upper limits of soil erosion rates for Europe, i.e. any actual soil erosion rate at which a deterioration or loss of one or more soil functions does not occur, are estimated to 1.4 t ha^{-1} yr^{-1} which is 3 to 40 times lower than actual soil erosion rates from tilled arable land in Europe (Verheijen, Jones et al. 2009). Growing winter crops reduces soil erosion rates by up to 10 times compared to bare soils in Europe (Cerdan, Govers et al. 2010). On the short term the occurrence of gullies may provide inconveniencies for field operations especially harvesting. However, erosion rates of about $50m^3$ ha^{-1} yr^{-1} on a particular field and the occurrence of gullies are necessary to inhibit operations on a field and to constitute serious conditions for the farmer. And even then, financial losses are relative small compared to off-site losses (Boardman 2013).

Decision-making processes: Planting winter cover crops is a robust coping measure to reduce the general vulnerability of the ground to erosive effects of surface runoff. The purpose is to aim for the long-term effect and consequences rather than any short-term single event consequences within a seasonal or annual time scale. The decision on planting cover crops has to be made early enough so that cover crops have enough time to capture nutrients and get established to withstand wet winter conditions and contribute to prevent surface runoff and thus soil erosion and nutrient leaching. The timing of planting cover crops is strongly dependent on the type of cover crop and especially the type of the preceding summer crop and its timing for harvest. To keep flexibility in the crop-shift period with respect of the timing of harvest and the choice of winter cover crop the decision on planting winter cover crops should be in July/August (Perrott and Baughen 2015). The criteria for an upper limit of acceptable amount of soil erosion within one year can only be determined theoretically (as a statistical mean value) and has no operational impact on decision-making. Decisions on soil erosion are made in context of the risk of precipitation events and individual valuation.

The critical situation arises when the erosion rate for the coming season (especially October-February) is expected to be above an acceptable limit (*1.4 t ha^{-1} yr^{-1} or $50m^3$ ha^{-1} yr^{-1}*).

Decision on type of cover crop and timing for plantation

The decision on the type of cover crop and the timing of plantation are closely interlinked and condition each other to a great extent.

Hazard: The timing of plantation is very dependent on the climate conditions in the period of crop-shift operations. In general autumn- and spring-sown crops are especially problematic providing vulnerable periods at which soils remain bare without protecting vegetation cover

(Burt and Allison 2010, Boardman 2013). E.g. winter cereals require in average a period of two months to gain a crop cover value of about 30% which is enough to provide adequate protection for the soil (Boardman 2013). Within this vulnerable period which lasts around 2 months one single erosional event triggered by a short-term convective rainstorm is already enough to destroy a newly planted field by eroding seeds and young crops (Perrott and Baughen 2015).

Decision-making process: The knowledge of a possible very wet transition period gives the farmer the opportunity to avoid this period and postpone or bring forward the crop-shift (Perrott and Baughen 2015). The timing of the crop-shift-period also determines the type of winter crop which shall be planted. The later the planting date the higher the required growth rate of the winter crops to be resistant to low temperatures and wet winter conditions (Knasckeil 2015, Stevens 2015, Wastenage 2015). If the crop-shift-period is earlier than usual due to expected wet weather conditions in October, harvesting activities of the summer crops have to be adapted which possibly requires the organization of additional machines and staff to bring in the harvest more efficiently (Stevens 2015). The timing of this decision should be in summer when plantation of winter cover crops should be happening in case of a wet autumn. July/August is suggested by local farmers from Devon (south England) as date where information on autumn/winter conditions regarding rainfall and soil temperature is desired (Perrott and Baughen 2015).

The critical situation arises when convective rainfalls hit bare fields after sowing impend to erode newly planted crops especially around October.

Buffer system characteristics

The link between rainfall and surface runoff which provokes soil erosion and nutrient leaching is buffered by the soil system. Surface runoff is generated mostly by saturation excess, where continuous rainfall raises the water table to the soil surface or sometimes by infiltration excess where rainfall rate is greater than the infiltration rate. For erosion to occur the shear stress of the moving water must exceed the shear resistance of the soil surface. Geology, topography and especially soil characteristics and its physical and chemical properties as well as vegetation do control surface runoff and erodibility of the ground (Burt and Allison 2010). Despite the buffer function of the soil systems the turnover of soil water seems to be rather high, since runoff generation and especially soil erosion events are strongly related to rainfall events. Especially individual high magnitude short-term rainfall/runoff events are responsible for a great deal of soil erosion. However, to account for most erosion moderate to large rainfall events need to be monitored over a longer period of time (Boardman 2006, González-Hidalgo, Luis et al. 2009). Thus, the buffer capacity of soils is in general very limited and readily exceeded by prolonged or especially high magnitude events. On the other hand, the storage characteristics of the soil system are very dynamic and mediates the local interaction of fluctuating water supply (rainfall) and demand (potential evapotranspiration) (Milly 1994, Porporato, Laio et al. 2001).

Referring to the final consequences (ability to grow crops) of soil erosion the soil system provides another kind of buffer function with respect to climate impact since it takes several decades of erosion (i.e. aggregation of erosive events) to cause significantly reductions in crop production. Thus, soil erosion is a long-term problem at which, however, climate may not even be the dominant factor. Slaymaker (2001) states that certain changes land-use practices are likely to have greater impact on erosion rates than any climate change scenario (Boardman 2006).

Critical climate conditions and climate information

Critical climate conditions

Necessary rates of rainfall to produce soil erosion are very dependent on the specific site but they are in the range of tenth of mm in a couple of days. For the South of England it is determined for at least 30mm within a two-day period (Boardman 2013) or short duration convective rainstorms with rainfall rates with at least 10mm h^{-1} (Fullen and Reed 1986). For that reason information like mean rainfall of the wettest month or mean values on maximum rainfall, or subsequent indices derived from such data are no useful indicators to assess erosion potential (dePloy, Kirkby et al. 1991). Critical climate conditions for general soil erosion are not to be defined since mean erosion rates for Europe are already critical under normal climate conditions (Verheijen, Jones et al. 2009).

Critical climate conditions for erosive events are high magnitude rainfalls over short periods of time (30mm in 2 days or 10mm h^{-1}) during a period of 2 months in autumn.

Climate information

Decision on planting cover crops: Short-term high magnitude rainfall events within a period of about 3-4 months (October-February) are critical for soil erosion. Information on mean max values on precipitation for this period would be desired climate information since mean values on precipitation have little information on individual high magnitude events which are identified as critical for soil erosion (Stevens 2015, Wastenage 2015). Also the relation of forecasts to the past 1-5 years may be of greater value for the decision maker. Since recently past years can be remembered, the significance of the forecast can be assessed on the basis of personal experience instead of a statistical mean value (Knasckeil 2015, Perrott and Baughen 2015). Decision-making processes require a lead time of 2-3 months to keep alternative decision options available.

Decision on type of cover crop and timing for plantation: To cause the flushing of newly planted crops one single erosive event exceeding the threshold of 10mm h^{-1} or 30mm in a two-day period can already be critical for the vulnerable 2-month period around October. Thus, required climate information should ideally resolve such events to be useful. The period of concern for such events is a two month period around October. Decision-making processes require a lead time of 2-3 months to keep alternative decision options available.

Vulnerability attributes

Criticality of decision-making processes: soil erosion in the context of land management has a destructive impact. Thus, the role of climate is that of a hazard which do affect agricultural activities but are not fundamental for the sector. The decision on whether to plant cover crops is rather specific problem for the CDE region. In the context of political regulations even on European level, the use of cover plants to mitigate soil erosion and nutrient leaching may become mandatory (Knasckeil 2015). However, considering the overall criticality of the problem this is very significant since the availability of fertile soil is the basic requirement for growing crops. In this long-term context, climate may lose relevance since land-use practices are likely to have greater impact on erosion rates than any climate change scenario (Slaymaker 2001).

The criticality of the decision on 'type of cover crop and timing for plantation' is much more significant compared to the decision on planting cover crops since no robust decision option with respect to land-use practices is available. Climate is dominating this problem and adding a great deal of uncertainty. However, the overall criticality of this decision is relatively low, since the worst case scenario would be a lost harvest (in case the cover crops are cash crops) and thus some economical losses.

Usability of S2D climate forecast information: the individual high magnitude rainfall event is not of major concern but the total amount of eroded soil within one year. Therefore mean values are of general use, however information on the distribution is desired since mean values on precipitation have little information on individual high magnitude events which are identified as critical for soil erosion. The required knowledge on precipitation distribution increases the uncertainty of the climate forecast and thus the informational output. The available S2D climate forecast for LMTool aims for precipitation with a temporal resolution of 3 month from October to February. This information seems therefore of general use whereat the integration of all autumn months would be desired.

The temporal scale of the forecast and the scale of the critical climate conditions deviate significantly. Information from a climate forecast with a 3 month temporal resolution as it is currently available is linked to significant uncertainty and decision-making is thus rather risky. Furthermore, climate information for the autumn month would be desired which contradicts the available S2D climate forecasts which aims for the period from October to February.