Integrating establishment practice and plant quality

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ABSTRACT

The matching of species to site is of fundamental silvicultural importance. Considerations include information on previous land-use/crop, soil type(s) and climatic factors. Furthermore, at establishment a suite of silvicultural options may be considered including cultivation methods, fertilisation regime, time of planting and weed and pest control issues. In addition there is the influence of plant quality (age. size, method of production, storage) which can further influence early survival and growth of outplanted stock.

We describe the development of an Establishment Management lit formation System [EMIS] decision support tool that integrates existing silvicultural advice for tree establishment in upland forest restocking in Britain, on a site-specific basis. It draws upon information from many technical and scientific publications to provide the user with acceptable (site constrained) tree establishment options for restock sites. Site information (user input) allows calculation of environmental variables which constrain species choice, via integration with the Ecological Site Classification (ESC) decision support system and identifies appropriate on-site management practices. System development is guided by operational requirement and existing knowledge. EMIS output will be available as both FITML and pdf delivered via the web, however, the constituent models arc also available as document-wrapped style web services to allow integration with spatial data (GIS) systems. This will enable delivery of spatially explicit good practice guidance in the future. Currently within Ireland the opportunity exists to develop similar systems based on the National Forest Inventory and other government agency datasets, existing technical publications and expert knowledge to ensure appropriate species-site matching and good silvicultural practice is adopted.

INTRODUCTION

National forest policies have expanded recently to include 'sustainable forest management' as an objective (Lane and McDonald 2002). Silviculture should ensure that any activity in the forest assists the achievement of the objectives defined by the manager (Smith 1986, Mason 1997). The first step in delivering sustainable forest management is the correct application of silvicultural knowledge at establishment, upon which all other decisions depend (Ray and Broome 2003). Such considerations, applied to a restock setting, include forest soil type (e.g. use of appropriate cultivation), operational impacts (e.g. minimising chemical use according to site specific needs) and timber production (e.g. identifying productive species well-suited to the site). In particular forest design planning has a wide range of 'competing' goals that the forester has to appreciate and account for (Bell 1998): where interaction between ecological (and social) components exists decision support system (DSS 1/) tools are useful (Rauscher et al. 2000). A key feature of DSS tools is that the decision-maker is an important part of a DSS. providing critical judgement and values that often dominate the decision-making process.

Whether reforestation or afforestation is involved successful tree establishment on upland sites requires knowledge of site constraints. These constraints include the general site environment (e.g. soil type, lithology, soil moisture and soil nutrient status), an understanding of the local climatic environment (e.g. wind climate, oceanicity. elevation, temperature profile), and the

1/ DSS tools are computer-delivered programs that provide support to the decision makers engaged in solving various semi-t ill-strzwatred problems involving multiple attributes, objectives mid goals (Turban and Ammon 2000).

interactions between these factors. The ability of the forester to assess site conditions and select well-suited tree species is therefore of fundamental importance, as is an understanding of the silvicultural options available to improve tree establishment and growth (Tabbush 1988). Silvicultural options include plant species and provenance choice (Morgan 1999), plant type, plant quality, plant storage and time and method of planting (e.g. Morgan 1999. McKay 1997), site cultivation (Sutton 1993, Paterson and Mason 1999), fertilisation (Taylor 1990a,b; Smith and McKay 2002) and vegetation management (e.g. Willoughby and Dewar 1995, Willoughby ct al. 2004).

We describe a prototype expert system (EMIS), developed for establishment of forests in upland Britain to help with compliance to sustainable forestry guidelines. EMIS attempts to present the complex interactions between site constraints and silvicultural options to improve establishment success and tree growth. Good practice guidance is web-delivered by providing recommended options for cultivation, fertilisation and aspects of 'plant quality' after species choice is matched to site constraints.

THE SYSTEM

The EMIS software integrates with the Ecological Site Classification system (ESC: Ray 2001). The ESC DSS uses models to assess tree species dependent upon six Ecological Site Classification (ESC) factors as criteria for testing site-species suitability (Pyatt and Suarez 1997, Pyatt et al. 2001):

- four climatic factors: accumulated temperature, moisture deficit, windiness (by Detailed Aspect Method of Scoring; DAMS; Quine and White 1993) and continentality,
- two soil quality factors: soil moisture regime (SMR) and soil nutrient regime (SNR).

EMIS integrates with the ESC tree species suitability model and provides additional species-specific silvicultural and plant quality guidance (Perks et al. 2006).

Development of an integrated treatment prescription

On selecting the EMIS programme, the user is required to input site-based assessment information. The first input is location, then dominant soil group is chosen from a drop-down list of 14 classes (Figure 1), and their attendant soil types (Kennedy 2002). Underlying lithology is also chosen from a drop-down menu within EMIS: underlying solid lithology can be obtained and input, for Britain, from British Geological Survey (BGS) maps or from the online BGS 'survey data portal'. A user is encouraged to check and input soil information after a comprehensive soil survey at the chosen restock site (Kennedy 2002). Accurate soil based information is imperative as choice of both cultivation and fertilisation regimes arc dependent upon correct soil

Figure l. Screenshot of ESC-required EMIS input to constrain species .suitability and good practice cultivation and fertilisation advice. Soil type, lithology and Calluna information are presented as user selected drop-down lists, whilst peat depth is a check box al peat depth > 30cm).

identification (Paterson and Mason 1999, Talyor 1990 a,b). Soil quality (SMR, SNR) is estimated using soil type directly, as modification (refinement) by site vegetation assessment, such as is required by ESC to identify native woodland type, is often not feasible on restock sites due to a lack of vegetation. However this functionality is retained within the EMIS architecture and will allow extension to non-restock sites in future. Further modification (user input) with respect to the presence of heather and the depth of peat are required as these factors are known to affect site fertility and hence alter nitrogen fertilisation guidance (Taylor 1990b: Figure 1). Soils information is therefore the primary driver for good practice advice for cultivation and fertilisation options (Figure 2).

The ESC models are interrogated, then captured site values, for the six constraining environmental site factors (four climatic and two soil factors) are displayed within EMIS. The user can alter any of these set-up parameters using local knowledge. The ESC models arc then interrogated and species yields are estimated from accumulated temperature, modified by the most limiting ESC factor. Species suitability (and predicted yield class) are assessed against the continuous suitability functions that have been developed within ESC (Ray et al. 1998) for the ten conifer species and two birch species considered by EMIS for upland restock sites. The EMIS parameterisation therefore operates by calling the relevant ESC models 'behind the scenes'.

Output

Once the user has selected one (or more) species from the suitability screen the EMIS system then presents all existing guidance on appropriate silvicultural options for a site, based on input site-based survey information and the captured constraining factors. Common plant type morphological specifications arc provided for seedling trees raised under either cell grown or bare-root stock production systems. Plant morphology (size classes denoted by acceptable height and root collar diameter ranges), and cell sizes for container grown plants are given (cf. Morgan 1999). Target root:shoot ratios (a measure of morphological `balance' and sturdiness) are also highlighted (see Landis this volume). Information regarding acceptable physiological limits (as arc routinely assessed by the physiological plant quality test root electrolyte leakage (REL) assessed at despatch from the nursery) are also presented to the user (e.g. McKay and Mason 1991, McKay 1997, McKay and Howes 1996, Morgan 1999). As the development and validation of other methods of plant vitality assessment occur, such as shoot electrolyte leakage (O'Reilly and Keane 2002, Bronnum 2005), chlorophyll fluorescence (Perks et al. 2001, 2004) or molecular techniques for identifying the development of cold hardiness (Joosen et al. 2006). information regarding these options can be introduced to the system database.

In Figure 3 we have used expert knowledge and unpublished experimental data to present guidance regarding acceptable planting

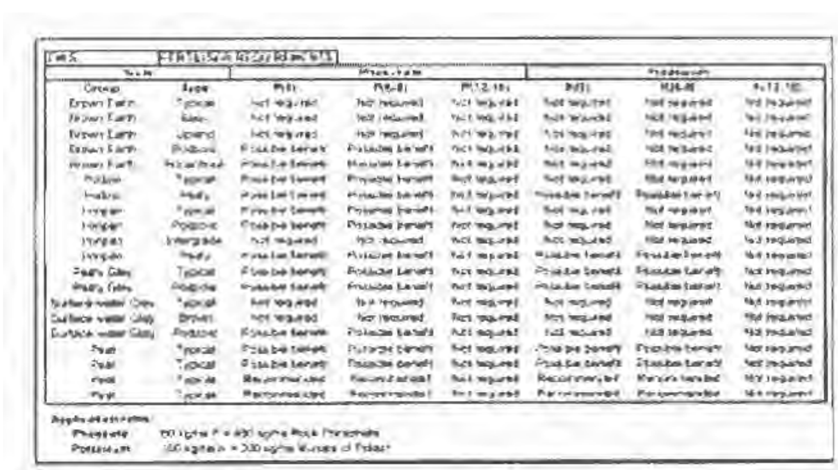

Figure 2. Sereenshot of the EMIS good practice guidance database sheetfin· Phosphate and Potassium applications, during the establishment phase, .for lodgepole pine (Pin us commit!). The specific guidance for an individual soil group and type is delivered to the user as web-based and optional .pdf output.

windows for container-grown seedling trees in the UK.

Acceptable planting windows in upland Britain, which depend on plant specifications and the climate zone of the planting site (captured from an accumulated temperature map: see Figure 3, Morgan 1999) arc also presented in tabulated format. Climate zone is divided into three broad categories of accumulated temperature where a warm site has greater than 1350 day degrees above 5°C, an intermediate site type has 1050-1350 day degrees above 5°C, and a cold site experiences less than 1050 day degrees above 5°C. Guidance on acceptable planting windows has been developed from operational experience allied to the interpretation of post-lift and post-storage REL tests as a measure of plant vitality for bare-root seedlings. Far containerised stock, guidance is based primarily on expert knowledge as extensive research on application and interpretation of measures of plant quality and their correlation to outplanting performance is lacking. The period identified for use of cold-stored stock relates to the period of soft shoot growth in non cold-stored material, though these windows will vary slightly dependent on nursery location, species, seedling age and climate. Furthemtore, plant cold tolerance at ti me of storage, which is dependent on previous climatic conditions, has a direct influence on the maximum acceptable storage duration, and therefore appropriate windows for planting of this stock type. Likewise, decisions regarding appropriate planting windows in the winter months and extension of planting into June and July should be taken based on examination of local site conditions. Moist (spring/summer) and unfrozen (winter) soil is required to ensure good establishment success of container-grown trees. Acceptable on-site storage periods for cell grown stock are considerably longer where plants can be left standing on a free draining substrate, though watering during extended storage periods is essential.

The EMIS web-browser interface delivers all the appropriate guidance whilst the user can also obtain the output in pdf format, for any number of scenario runs.

Implementation

During development, linkages between EMIS modules and among tools developed within the EMIS framework architecture were considered using the Simile scheme. EMIS alone has been developed with reference to approximately forty technical and scientific publications regarding site-species suitability and the attendant silvicultural management options. By delivering EMIS as a web application, maintenance is reduced as the software and data are held centrally; potential users simply require a web browser. To provide GIS interoperability, which in the Forestry Commission is based on Microsoft.NET technology, some functionality was exposed as document-literal wrapped web services (Butek 2003). Inclusion of this

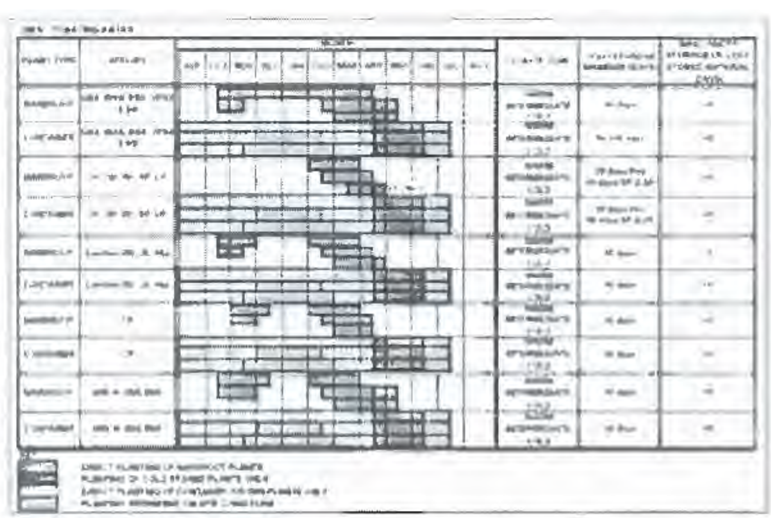

Figure 3. Screenshot of the EMIS good practice guidance database sheet for acceptable planting windows. The specific guidance for a specific species is delivered to the user as web-based and optional .pdf output. Species codes are as in Morgan (1999).

technology will enable EMIS to deliver decision support to both strategic (i.e. spatially through GIS) and small-scale users, within the British forestry sector.

Interoperability

A key to effective decision support for ecosystem management is the interoperability of a variety of systems allowing components to co-operate by exchanging data. EMIS displays interoperability at software and model level with the site classification DSS ESC. Linkage with the Hylobius Management Support System (HylobiusMSS: Moore 2004) and Herbicide Advisor tool (Thomson and Willoughby 2004) are in development.

Operational scale and use

EM IS has been designed initially for use at the stand scale. Within the British national forest estate a spatial (GIS) planning tool 'Forester GIS' has been developed (Suarez et al. 2003) as an extension to AreView-GIS platform (ESRI, Redlands, California). The development of ESC as an extension to AreView-GlS has been demonstrated, allowing the suitability of tree species to be analysed spatially using the same six site factors (Clare and Ray 2001). In recent trials, remote calls from the GIS system to EM IS modules have provided 'proof-of-concept' of the interoperability of these tools, thereby enabling a spatial landscape-scale delivery of good practice guidance to the forest planner in the future.

Whilst experienced foresters will have appropriate species, plant types and silviculture in mind when restocking sites, EMIS may be consulted to provide a check. the added-value being that any new research or guidance can be centrally updated. Forest planners may consider inappropriate species (e.g. for landscaping reasons) and EMIS would identify such instances. The guidance ensures suitable silviculture, appropriate species with yields are achieved to confront with the requirements of 'The UK Woodland Assurance Scheme' (Anon. 2000).

Future developments

The development of web-based establishment silviculture and plant quality guidance for Irish conditions is possible using existing standards (Forest Service 2000), published information regarding acceptable nursery tree physiological limits (O'Reilly et al. 2001. 2002; O'Reilly and Keane 2002), seedling morphology (Thompson and Lowe 1999a, b) and silviculture (Horgan et al. 2004). Such guidance can be linked to the application of expert knowledge, where published data is unavailable, and spatial (climate) data such as arc available from the Environmental Protection agency (McGrath et al. 2005).

The non-spatial EMIS decision support tool described here is in an advanced stage of development, and will be released in 2006, following testing by research and field specialists. It is intended that the silvicultural management options will be evaluated against a set of sustainability criteria, which will be developed and applied by an expert panel of stakeholders, in order that the user may more clearly define and balance the ecological and production objectives that forest management must meet in the 21st century. Furthermore, EMIS can utilise the ESC models to provide species-specific predictions of species suitability under future climate change scenarios, provided by the UK Climate Impacts Programme (Huline et al. 2002), which are outwith the normal experiential knowledge of foresters. In Ireland existing future climate scenarios arc available (McGrath et al. 2005) and development of guidance and scenario testing of species choice with changing climatic conditions could also be implemented.

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