CLIMADAPT

CLIMADAPT is a web-based decision support system for guidance on forest species suitability under current and future climate change scenarios. The CLIMADAPT project was funded by COFORD, Department of Agriculture, Food and the Marine

Department of
Agriculture,
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An Roinn
Talmhaíochta,
Bia agus Mara

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Introduction

Matching well suited tree species to different site types is the first and most fundamental step of sustainable forest management. Ecological Site Classification (ESC) has in the past provided support on ecological suitability analysis and site yield estimation for forest managers in other countries, and more recently has been used to consider changes in suitability and yield resulting from different climate change scenario projections. The objective is to provide decision support to forest managers and policy makers, using soil and climatic information for Ireland that can be used to assess changes in species suitability and yield resulting from different climate scenarios. Future projections suggest that both medium-low and medium-high scenarios for green house gas emissions will induce warmer, drier summers in the south and east of Ireland. This may affect growth and yield for drought sensitive species such as spruce, beech and ash. This will allow wide access, use and application to practitioners in Ireland; providing information and knowledge to underpin sustainable forest management in a century of global climate change and increased woodland expansion.

The CLIMADAPT system has the following functionality:

1. A web based user interface, capable of providing 'rich client' functionality over and above that of a conventional website. The interface will enable users to analyse spatial data using a set of GIS utilities.
2. Provision of a 'grid' spatial information suitable for display within the user interface.
3. Provision of point based information suitable for display and for use within calculations.
4. Enabling users to create and store map features.
5. Provision of a knowledge-based service providing textual descriptive information to be displayed within the user interface.
6. The system has two main functions:
    - **Stand analysis**: selection of suitable species under current (baseline) and future climates using 2050 and 2080 climate change projections based on Met Eireanns' c41 projections. The DSS is primarily a guide to species suitability, but indicative potential yield class is also included for 20 major current and potential species (see Ray et al 2009; Black et la 2010) for scientific background. Users are also encouraged to refer to the TEAGASC productivity map for Sitka spruce for a more in-depth analysis for Sitka spruce crops (Farrelly et al., 2009 a, b).
    - **Spatial analysis**: display of all ESC factors and other environmental constraints on species suitability and productivity. IN contract to the site specific analysis, this provides regional spatial data for the entire area under observation at a resolution defined by the user. For example, spatial analysis can be conducted on a country scale of for a specific area forest. Spatial functionality id provided for regional planning or development of other DSS. The functionality is supported by GIS databases located on the host server

How does ESC work ?

Forest growth, function and productivity are influenced not only by climate, but by the interaction of climate, soil type and site specific factors (Horgan et al., 2004). Site classification systems, which have been used in Scandinavia (Cajander, 1926) and central Europe (Ellenberg, 1988) to describe forest cover of regions, use biophysical variables describing site and climatic characteristics. An ecological site classification system (ESC) has been developed for Ireland (Ray et al., 2009), based on a similar GIS system for the UK (Ray, 2001; Ray et al., 2003). This system is also used to assess the

impacts of projected climate change scenarios (based on Met Eireann projections) on species suitability. Multi-factor forest site classification system use inputs to characterise biotic and abiotic influences on tree growth which are then used to provide support on selection species according to site type(Figure 1).

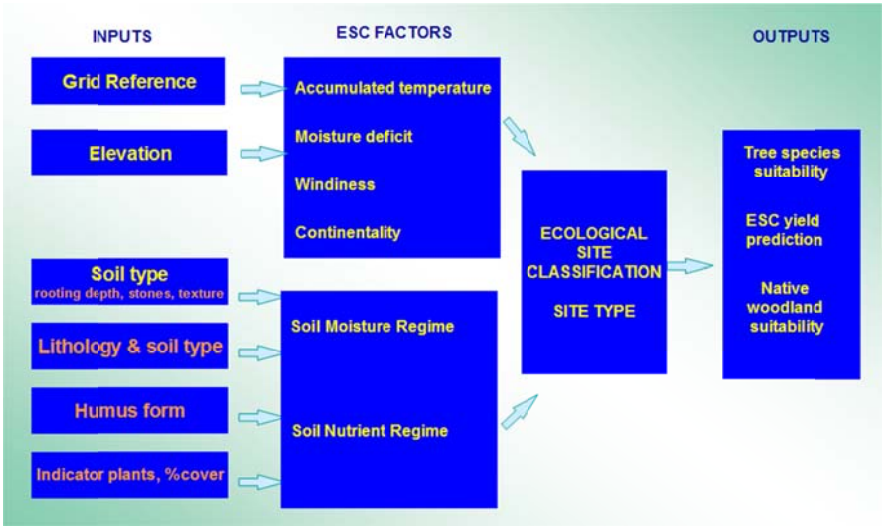


Figure 1: A schematic representation of required user inputs, EC factors and outputs from the CLIMADAPT DSS

The ESC approach describes the response of all major forest species in Ireland and the UK to four climatic factors: warmth (accumulated temperature - AT), droughtiness (i.e. moisture deficit - MD), wind exposure, and continentality (CT), based on Delphi models (see Pyatt *et al* 2001 for definitions). The suitability class (Very Suitable, Suitable, or Unsuitable) of different tree species was linked to each of the climatic factors, and to two soil quality factors representing soil wetness (soil moisture regime – SMR) and soil fertility (soil nutrient regime – SNR).

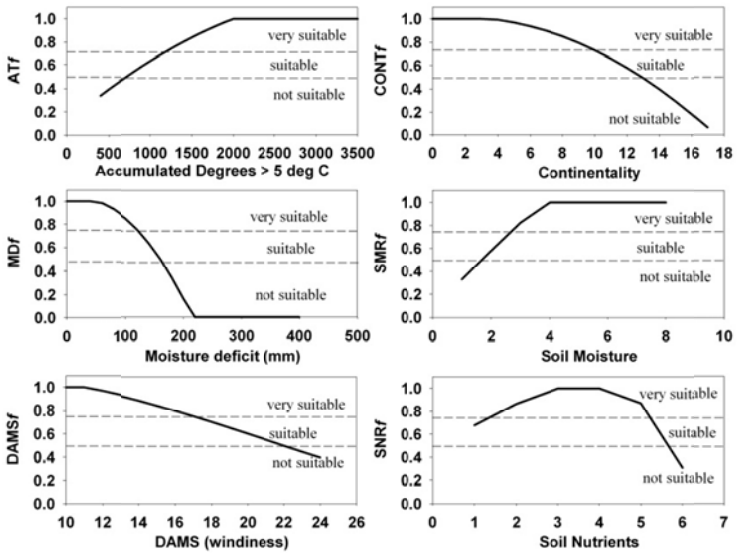


Figure 1: The suitability of Sitka spruce according to a) Accumulated Temperature (AT - day degrees above 5ºC) and b) Moisture Deficit (MD - mm), DAMS or windiness, continentality, SMR-soil moisture regime and SNR- soil nutrient regime. Suitability is classified on a scale from 0 to 1, where limiting factor (f) values >= 0.75 is very suitable (GYC > 20), >= 0.5 is suitable (GYC 10 to 20) and < 0.5 is Unsuitable (GYC < 10, see Ray et al., 2009).

Section 1: Registration

Site location and registration

Navigate to http://82.165.27.141/climadapt_client/index.jsp or CLIMADAPT portal on the COFORD website (insert link) using your web browser. For best results use Mozilla Fire fox, but **latest** versions of chrome or explorer will work as well).

1) Register your details

Register your details or logon if already registered (remember your username and password)

Figure 3: The Registration page

<Submit>

2) If you have previously registered, just enter user name and password

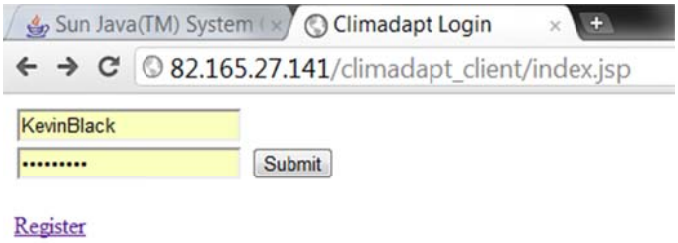


Figure 4: The logon page

Note: Ensure that pop ups are not blocked on your browser or that the antivirus does not block the execution of the web application. This can be done by changing your browser options (go to help for the specific browser you are using). Also, depending on the speed of your DNS line response times may be slow, so be patient.

Section 2: Stand analysis

The stand analysis window opens once you have logged on. The window has 4 menus on the top right of the screen a)Site, b) Stand, c) Delete and d)Report. The Spatial analysis can be selected on the bottom left of the screen (see section 2)

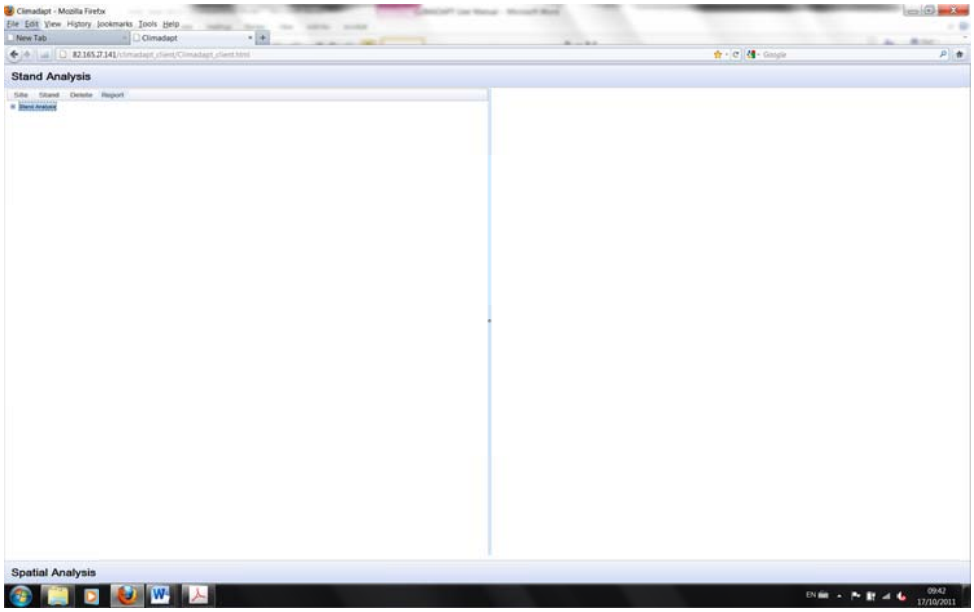


Figure 5: The webpage after logon is completed

2.1 Adding a site

Click **<site>** and **<add site>**

A google map will appear. Enlarge to required scale (click on the + or – icon or move map using direction icon, see red circle, Figure 6). The enlarged map below show a site selected in Cloosh forest

- Select site with mouse or enter grid reference
- Click **<OK>**
- When the site has been selected a red arrow will indicate the site and a grid reference

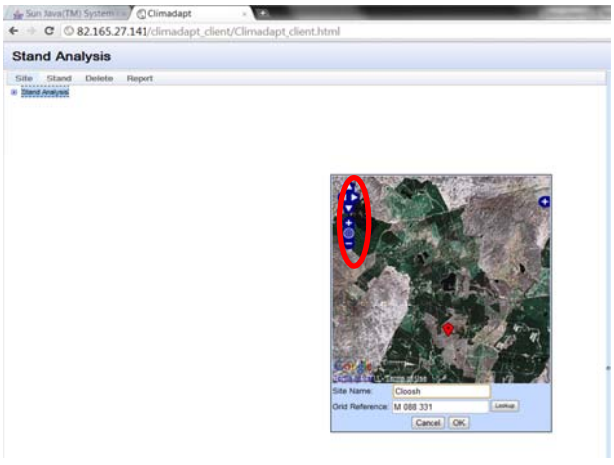


Figure 6: Selection of your site

Now, expand the Stand analysis directory (i.e. click in the plus icon next to stand analysis) to show sites selected (Figure 7).

Also expand the directory for your selected site (e.g. Cloosh), 2 boxes will appear a) site characteristic definitions showing that default soil characteristic are selected (i.e. SMR and SNR) and b) a results box with a drop down list for climate change scenario (in this example the baseline or current climate is selected).

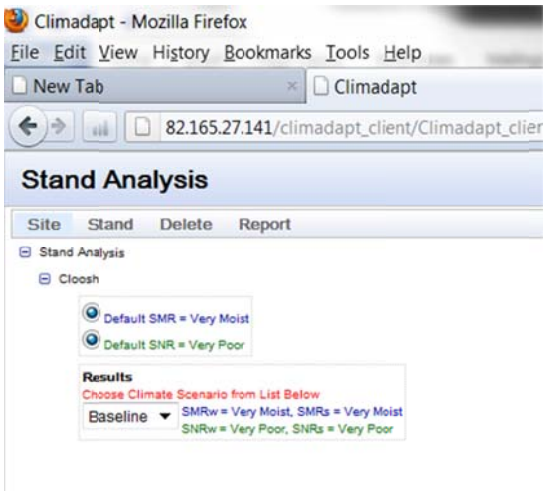


Figure 7: Display of your site characteristics and results options

2.2 Defining site characteristics

There are numerous options for defining the site characteristics. These vary in complexity depending on the amount of information the user wishes to include in the analysis.

2.2.1 Option A: Default selections

This option utilises underlying spatial data which specifies the soil moisture regime (SMR) and soil nutrient regime (SNR). These are based on the indicative soil map and functions using soil type as an indicator (Ray et al., 2009, Figure 1 appendix A).

Note: The definitions of SNR do not consider application of fertilisers. If fertilisers have been applied do not use this default option. Also the underlying soil mapped used is based on a model and is only indicative, so in some cased the underlying soil type and associated soils characteristics may not be correct. For these reasons we recommend using Option B or higher.

To display the results for species suitability click on the results box as shown in Figure 6a. A results window will appear in the left hand panel.

There are 2 option windows within this panel a) suitability (which is highlighted dark blue in figure 8b) and b) indicative yield which can be selected with the mouse (Figure 8b).

The suitability under future climate change can be selected from the drop down box in the results box under the site under analysis.

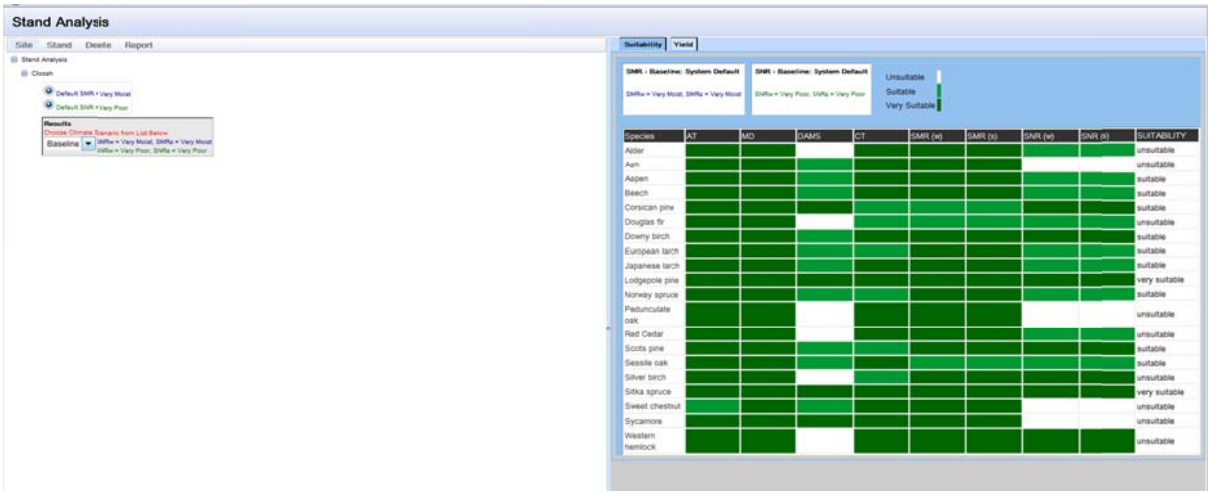


Figure 8a: Results panel selection and panel for species suitability for the baseline climate

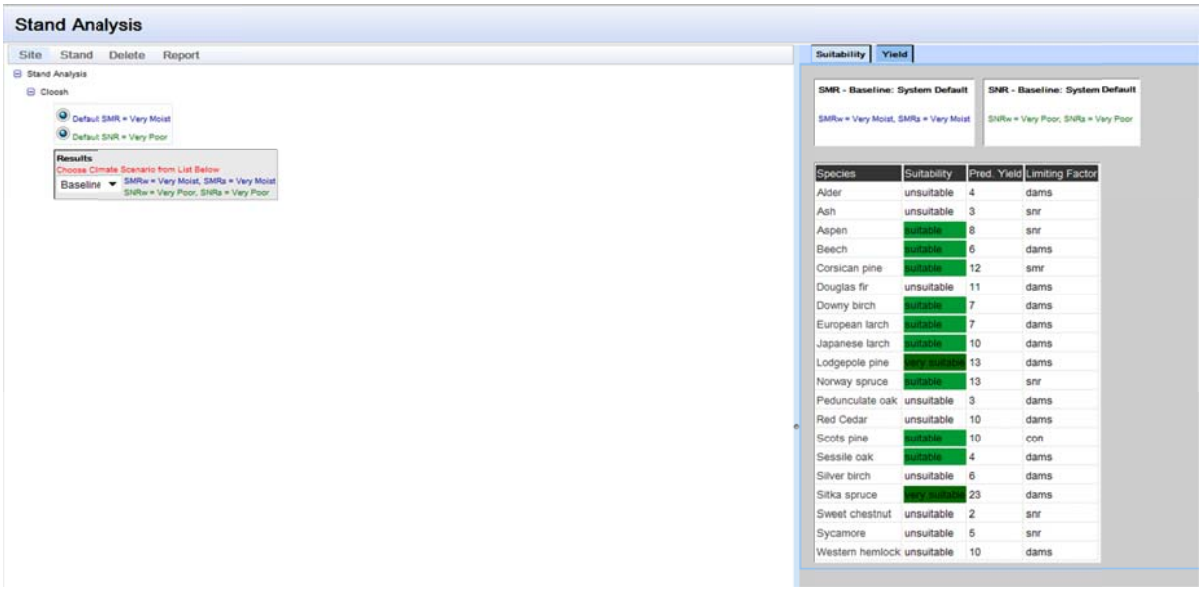


Figure 8b: Results panel selection and panel for indicative yield class for the baseline climate

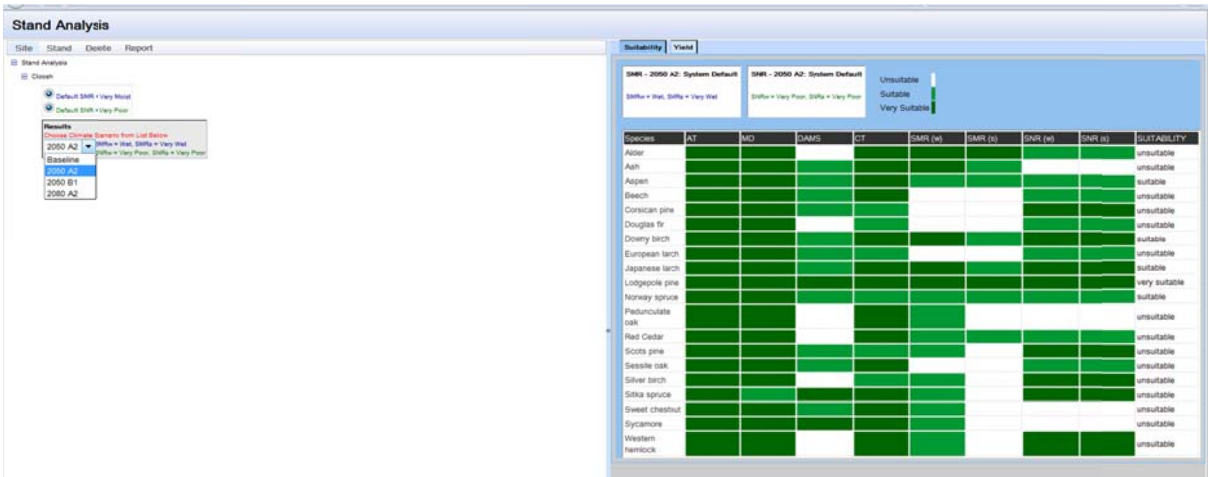


Figure 8c: Species suitability for the Cloosh site under future climate change by 2050 assuming the A1 scenario.

Interpretation of results

Species suitability: Species suitability under the selected climate scenario recorded as very suitable, suitable or not suitable in the text in the SUITABLILTY column in the results panel. The LIMITING factor is also shown in the adjacent column. In this example (Figure 8a) Alder is not suitable and the limiting factor is DAMS (wind and exposure). The suitability of species with regards to the ecological site classification (ESC) factors (i.e. AT, DAMS, MD, SMR, SNR and CT) are also shown as very suitable (dark green), suitable (light green) or not suitable (white).

The example shown in figure 8a relates to the current climate. Future suitability can be displayed by changing the climate scenario in the results box in the right hand panel of the stand analysis window (Figure 8c). *You will now notice that some species will not be suitable under future climate, although they are suitable under the current climate.* Periods up to 2050 or 2080 can be selected for these analyses. There are a range of scenarios (SRES) for climate change projections depending on global economic, population changes, regional factors, future reliance on fossil fuels and stabilisation assumptions. Only scenarios A2 and B1 are selected for this DSS since they reflect the medium to high (A2) and a high (B1) ranges of future climate change.

Indicative yield class: The indication of indicative yield is expressed as a general yield class in the Predicted Yield column (Figure 8b). This also provides the most limiting ESC factor and a suitability indication. The predicted yield does not consider increased or decreased in yield associated with the use of different provenances or silvicultural/management practice which can alter potential yield (e.g. cultivation or fertilisation). Suitability indicators assume a greenfield site.

For different provenances of Sitka spruce, there is a potential increase of 2 YC when Washington is planted instead of QCi, this can further increase if genetically improved material is planted. It should also be noted that provenances of Lodgepole pine or Douglas fir are not considered. Please refer to Horgan et al 2004 for guidance on provenance selection.

Dangers of using the default method

Experienced forester may notice that the suitability and yield for Sitka in the given example do not reflect the real situation. This is because the underlying soil spatial data is not correct for this site. Also, soils drainage of, or application of fertilisers to, the site are not considered when the default option is used. It is recommended that the default option is used as a last resource and results should be interpreted cautiously. It is always better to conduct a site visit and collect information outlines in options B below for a more accurate assessment of species suitability and potential yield.

2.2.2 Option B: Define soils type

Soil type is one of the most important indicators of suitability, particularly in relation to SMR. These can be beater defined for the site in question if the soil type is known together with information of rooting depth and stoniness. This method provides the best indicator for SMR. Although SNR is more

accurately depicted using option B, analysis of vegetation on site is the best to characterise SNR (see option D).

The identification of soils requires a bit of training and experience. Appendix 2 provides a basic guide to soils types using descriptions used in the National Forest Inventory. Soil scientists will always recommend digging a soil pit to view the soil profile before identification is attempted. To save time, look for exposed profiles near drains, road cuttings or uprooted trees. This can be useful to identify spatial variations in soils on the site if a layer from the profile is cleaned off with a spade along various points. If no soil profiles are visible on site, a soil auger may be used. If you are feeling extremely energetic dig a 1 m soil pit.

Please refer to the following guides for identification of soils in Ireland:

- A Guide to Forest Tree Species Selection and Silviculture in Ireland. Horgan et al 2004
- **Field guide: The identification of soils for forest management. Kennedy, 2002**

To utilise option B using the same example provided for Cloosh:

a) Select the **<Stand>** menu in the Stand analysis menu and select **<Define soil>** from the drop down menu (Figure 9, step a)
b) An extra box called 'Soil type' will appear in the right hand panel below the default box (figure 9 step b) . Click on this box to show the soil definition in the left panel of the Stand analysis window. This includes a drop down box for soil type specification and control buttons to modify SNR or SMR manually.
c) To access these controls you must first deselect the buttons for SNR and SMR (figure 9 step c).
d) Then select the toggle buttons in the Soil type box as shown in Figure 9 step d.
e) You can now enter the description for soils in the left panel

Figure 9a: Definition of soil type to characterise SNR and SMR

f) First select the soil type from the drop down list. For this site we know that these are flushed blanket peats as shown in Figure 10.

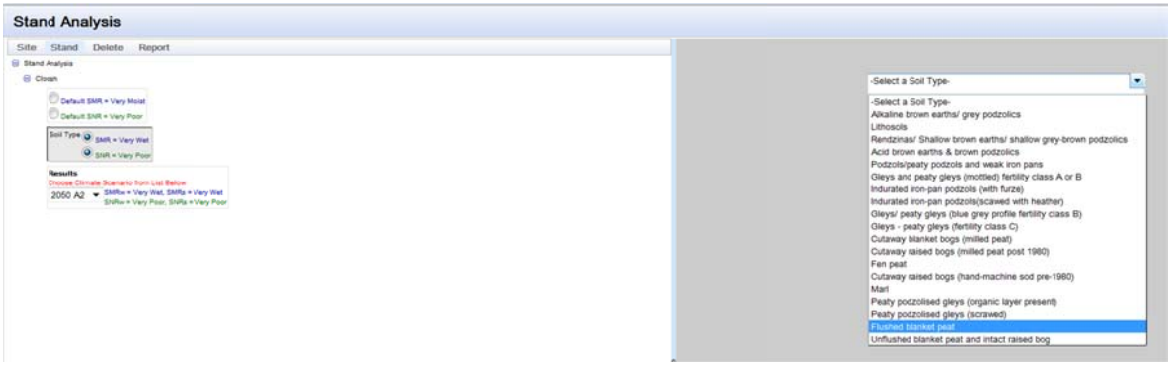


Figure 10: Selection of soil type

g) You will now notice that the SNR has changed to poor (P) and SMP has changed to wet (W) on the slide control scale

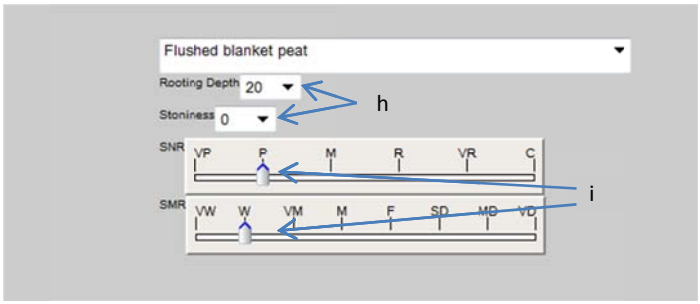


Figure 11: Changing rooting depth, stoniness and manual adjustment of SNR or SMR

h) The rooting depth default value (30 cm) for this soil type can be changes to the value obtained following your field visit. In this case we selected 20cm because the soil was very wet and evidence on site form blown trees suggests a rooting depth of 20cm (Figure 11, step h). The stoniness value of 0 % for this soil was deemed to be correct, so this value was not changed. Stoniness for some soils such a Lithosols, for example, can be very high (default is 15%).

i) The SMR or SNR can be manually changed by dragging the scale to the desired level depending on fertilisation or cultivation of the site.

To run results, click on the results box in the right hand panel.

You will now notice that prediction of species suitability is much better. When you compare figure 9a to Figure 12, you can see that only Lodgepole pine is very suitable for this site, as expected. The default method suggests that Sitka spruce was also very suitable, which in unlikely (figure 9a).

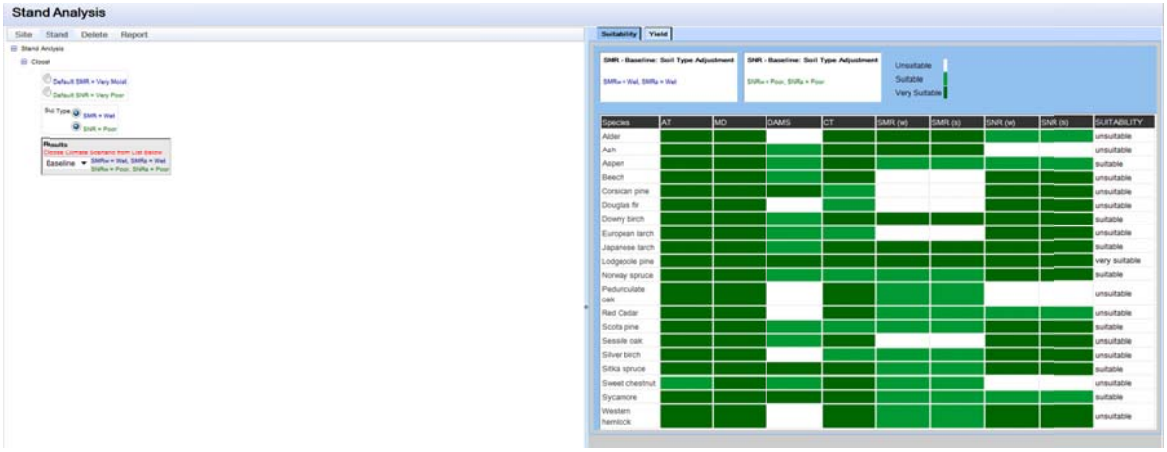


Figure 12: Results of the Cloosh site following user defined classification of soils type and modification of SMR and SNR

2.2.3 Option C: Specify Soil Quality

This option can be used if the user cannot visit the site and does not know the soil type, rooting depth etc., but they do have information on soil nutrient status and moisture, based on previous observation, laboratory results, archived data from the site. For this option, the SNR or SMR can be selected from a drop down list using expert judgement or the soil characteristic figure shown in Appendix A.

To utilise option C:

a) Select the <Stand> menu in the Stand analysis menu and select <Specify Soil Quality> from the drop down menu (Figure 13). An extra box called 'Specified Soil Quality' will appear.
b) Be sure to select the SNR and SMR toggle button in this box if option C is to be used. You will notice the appearance of 2 drop down box lists in the left panel. (Figure 13). These can be selected to best characterise the soils.
c) Run the results as before and note the difference in the predicted outputs.

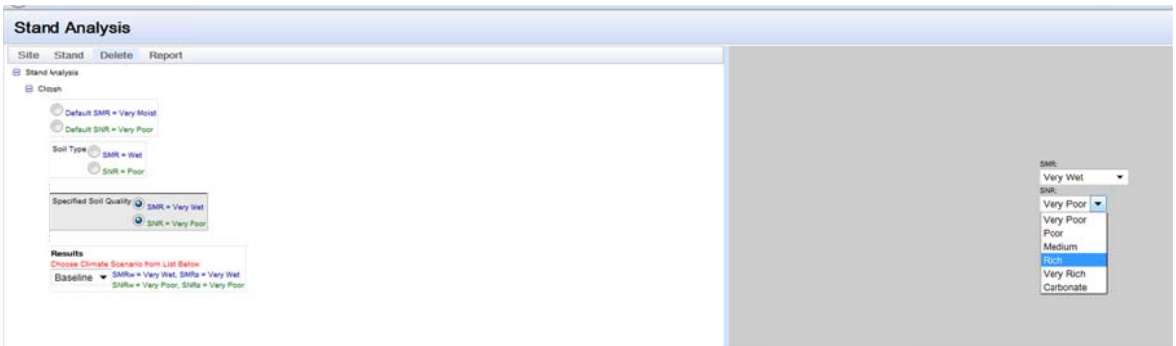


Figure 13: Specification of soil quality using option C

2.2.4 Option D: Specify vegetation

The best way to characterise the SNR on a site is to conduct a vegetation survey. Because this option does not modify SMR, it is best to use option B in combination with option D for SNR. The presence of certain key species is directly related to the soil nutrient status. For example,

Calluna vulgaris is often an indicator of poor SNR, while species such as *Geranium robertianum* (herb Robert) are indicators of good fertile soils.

Take particular care noting trees in adjacent forest sites or hedgerows. It is likely that ash, for example, might not be suitable if there is no sign of these species in the landscape.

2.2.4.1 A guide to vegetation surveys

Care should be taken when characterising vegetation because some species may occur on site temporality due to soils disturbance, so it is best to note as many species as possible with the relative ground cover in several quadrants (1 m^2). Try to identify different common patches where the vegetation populations are slightly different (i.e. different releves), but they are well representative of vegetation on site. It is much easier to identify species when they are in flower because most identification key use flower structure as the main guide. For these reasons, it is best to conduct surveys in Summer or autumn. Where, there is no vegetation cover in the forest understory, it is best to conduct a survey close to the site where soils are the same. The vegetation survey requires rather specialised knowledge, but with a good field guide book and some practise you can get good at species identification. The following field guide books are recommended:

- **Rose (2006). The Wild Flower Key. How to identify wild flowers, trees and scrubs in Britain and Ireland. Penguin Books ISBN 13 978-0-7232-5175-0**
- **Webb et al (1996) An Irish Flora (7th ed) Dundalgan Press. IBN 0-85221-131-7**
- **Page (1997) The Ferns of Britain and Ireland, Cambridge Press. ISBN 0-521-58658-5**

For example, assume you conducted a survey on the site in Cloosh and 3 quadrants you identified the following species and distributions:

Releve 1: Calluna vulgaris 20%, *Osmunda regalis (Regal fern*) 2 %, purple moor grass (*Molinia caerulea*) 10 % and *Sisymbrium officinale 2 % (wild mustard a species suggesting better nutrient status)*. This may suggest that the site was fertilised before because of the presence of wild mustard, but the low occurrence would indicate that SNR is not changed.

Releve 2: *Calluna vulgaris* 10%, *Molinia caerulea* 5 %, *Sisymbrium officinale 10% Vaccinium oxycoccos* 20 % and *Eriophorum angustifolium* (bog cotton grass) 10 %

Releve 3: *Calluna vulgaris* 20%, *Osmunda regalis* 3 %, *Molinia caerulea* 10 % and *Eriophorum angustifolium* 5 %

All of these species suggest a poor SNR

The compile the information under option D do the following:

a) Select the **<Stand>** menu in the Stand analysis menu and select **<Define vegetation>** from the drop down menu (Figure 14).
b) Select SNR in the 'Vegetation' box below the 'Specified soil quality' box in the right panel. Be sure to select SMR from either the 'Default', 'Soil Type' (recommended see figure 14) or 'Specified soil quality' boxes.

Figure 14: Selecting the vegetation specification to modify SNR

c) You will notice a new window in the left panel. To add species and distributions for the first releve (plot) place the curser in the open window and start typing the genus, you will notice a list appears and it updates as you type the species name (e.g. *Calluna vulgarus* for Cloosh). Select the species and it will appear under the species list in releve 1 (Figure 15). Now enter the percentage cover (20 using this example). The SNR bar on the slide rule above the species window may change if a species indicative of a different SNR is entered.

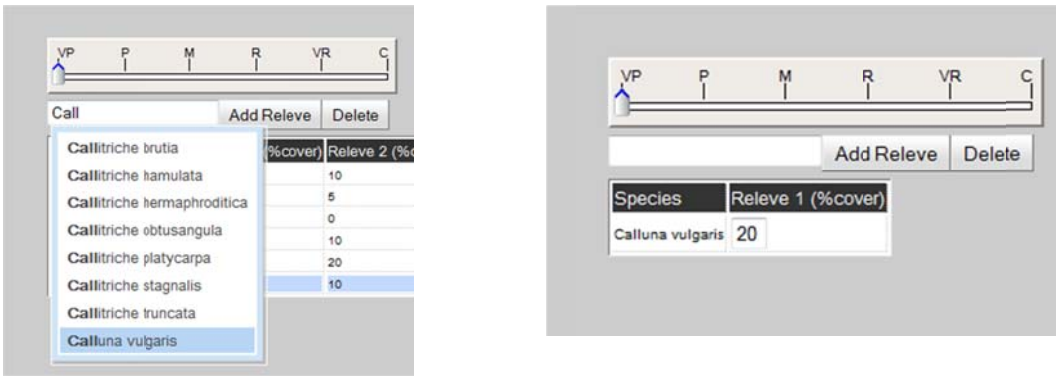


Figure 15: Entering species and % cover for different releves on the site.

d) Enter all the species identified in all of the releves in the site. If a species does not occur in a specific releve, enter the % cover as '0'. It is not always possible to identify all the species so the % cover does not have to add to 100%. Also in some cases there may be patches with no cover.

e) To delete an incorrect species entry highlight the entry and click <Delete>

f) To add a releve simple select <Add Releve> and filling the % cover of species entered. By the end your screen should look like the table shown below (Figure 16).
You may have noticed that the SNR has changes from Poor (P) when using option B to define SNR (see Figure 11) to very poor (VP) based on vegetation cover. (Figure 16)

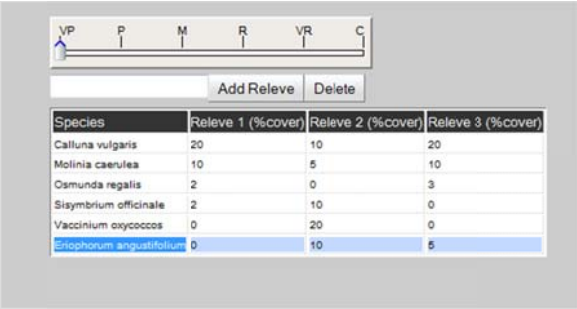


Figure 16: The completed species distribution table for Cloosh

Now run the results by selecting the climate scenario as before.

You can now see that Lodgepole pine is suitable (using the vegetation specification of SNR, Figure 17) compared to very suitable, when the Soil type characterisation of SNR is used (see Figure 12).

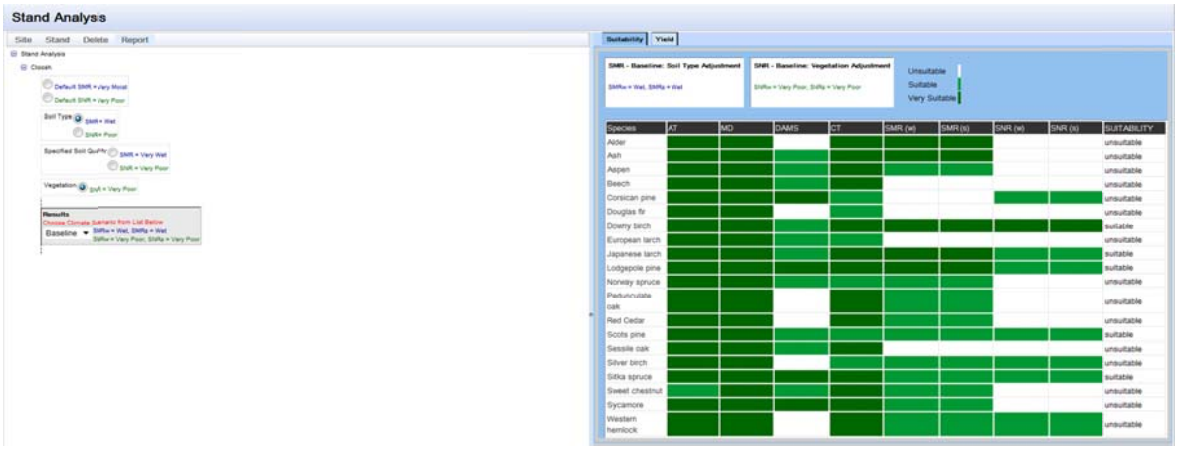


Figure 17: results

2.3 Running results, saving and printing result

2.3.1 Viewing results in the Stand analysis window

The results for any selected stand can be viewed by clicking on the results box located below the site name and site definition parameters. E sure that the correct options are selected for SNR and SMR before results are run (see section 2.2 Options A and B for details, you have done this before).

2.3.2 Saving and printing results as a pdf file.

The view the results data in a pdf file:

a) Select the climate scenario in the results section (see Figure 18). The ‚Suitability> and <yield> results should be displayed in the left panel.

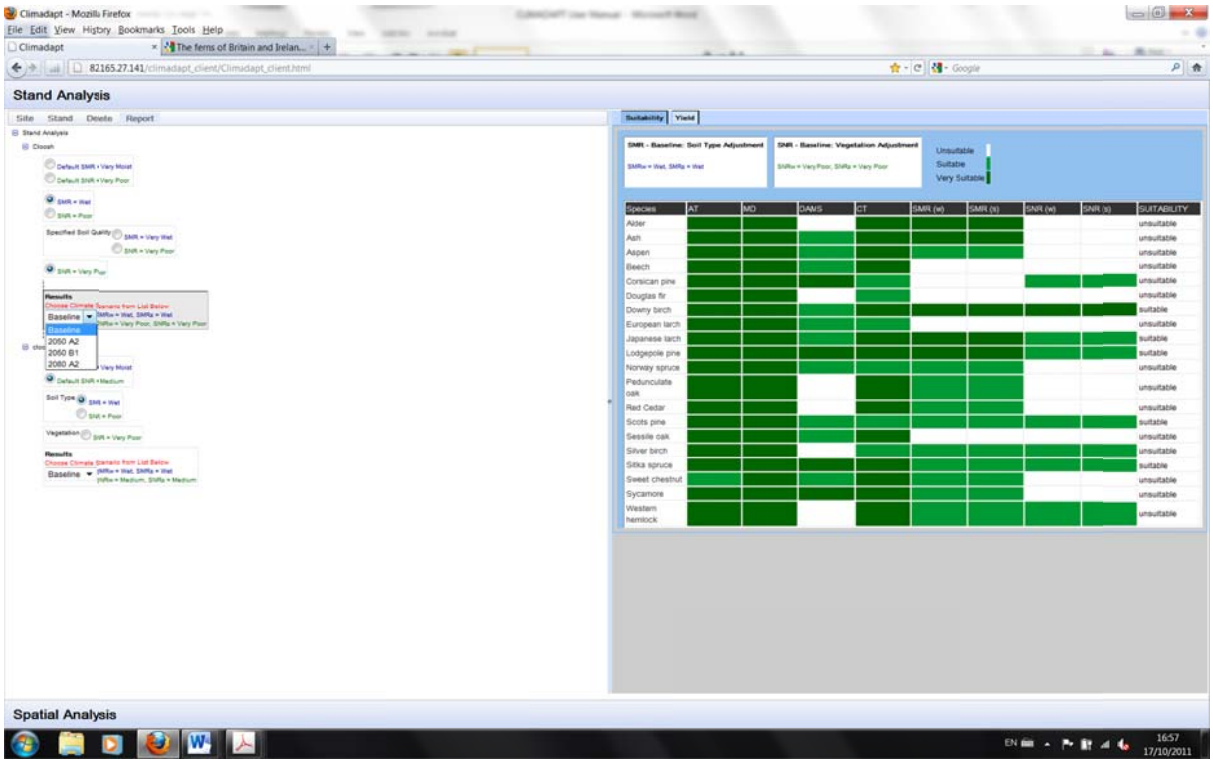


Figure 18: The results panel shown on the left hand side.

b) Now select <Report> from the Stand Analysis menu. A new browser page will open as pdf file (Figure 19). You can save or print this by selection the appropriate icon (circled in red). An example of a results file is provided below and a file called cloosh.pdf in your folder or cd.

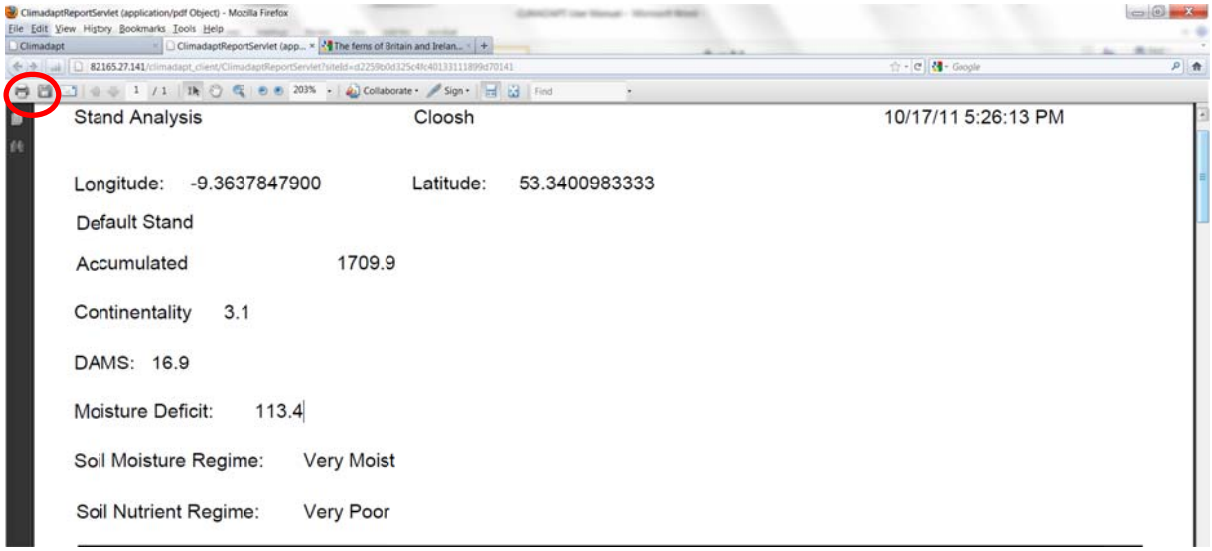


Figure 19 the pdf results page

The information listed includes site name, co-ordinates easting and north and climatic factors for the default climate (i.e the current climate), 2050 a2 (Figure 20), 2050 b1 and 2080 a2. Climatic factors include

- Accumulated (temperature) in this case 1840 day degrees above 5 deg C
- Continentality (3.5 in this case) sites with values greater that 1 are inland. Sites far in land have values of 7
- DAMS (16.9) indicative of moderate exposure, higher values indicate higher exposure.
- Moisture deficit -9999 (means surplus water). Deficit values are positive and vary from 0 to 400 mm.
- SNR and SMR using the selected definition option (A to D see section 2.2)
- The method used to calculate the SNR and SMR are show above the species suitability data (see Figure 21)

Figure 20: Climatic reports for future climate

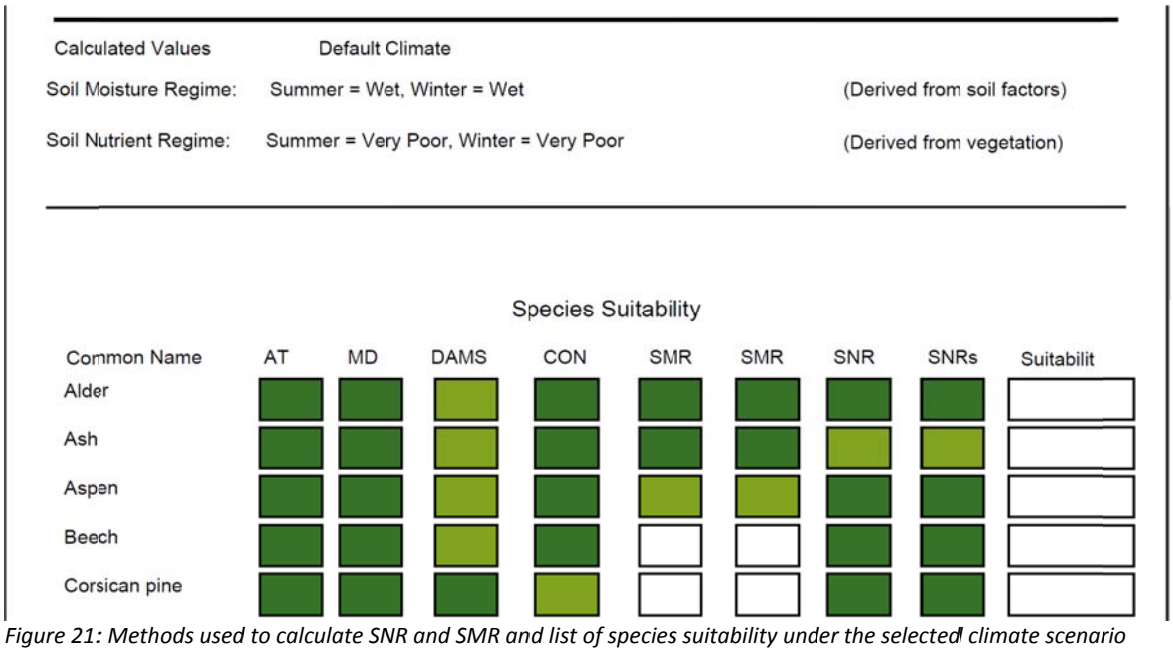


Figure 21: Methods used to calculate SNR and SMR and list of species suitability under the selected climate scenario (current climate in this example)

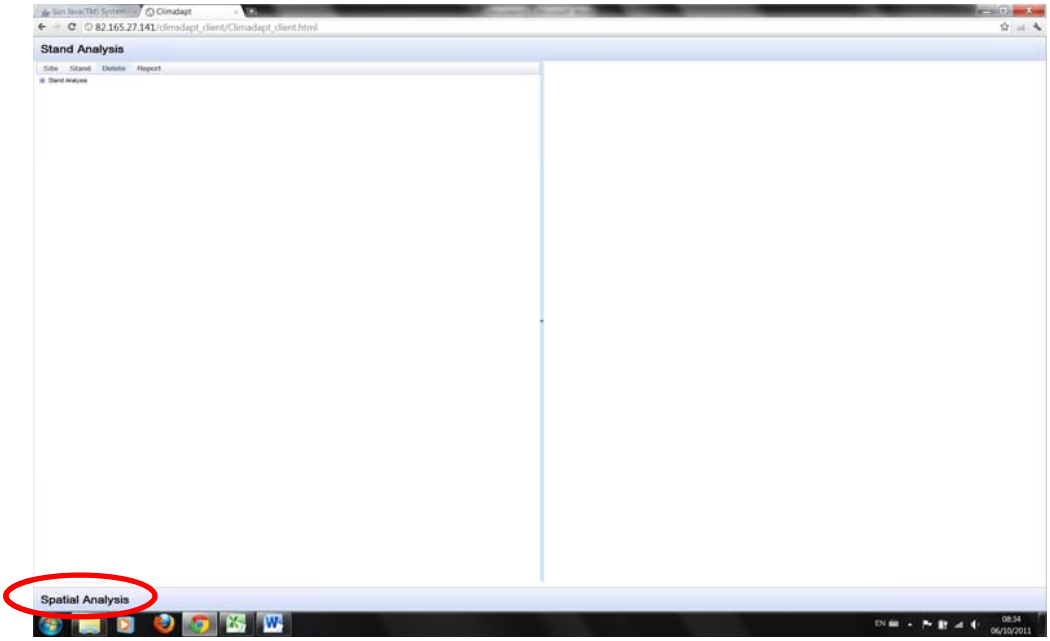
Species Yield

Common	Suitability	Pred. Yield	Limiting
Alder		3.57	dams
Ash		2.97	snr
Aspen		7.53	snr
Beech		5.83	dams
Corsican pine		12.44	smr
Douglas fir		11.37	dams
Downy birch		6.85	dams
European larch		6.66	dams
Japanese larch		10.22	dams
Lodgepole pine		12.68	dams
Norway spruce		12.86	snr

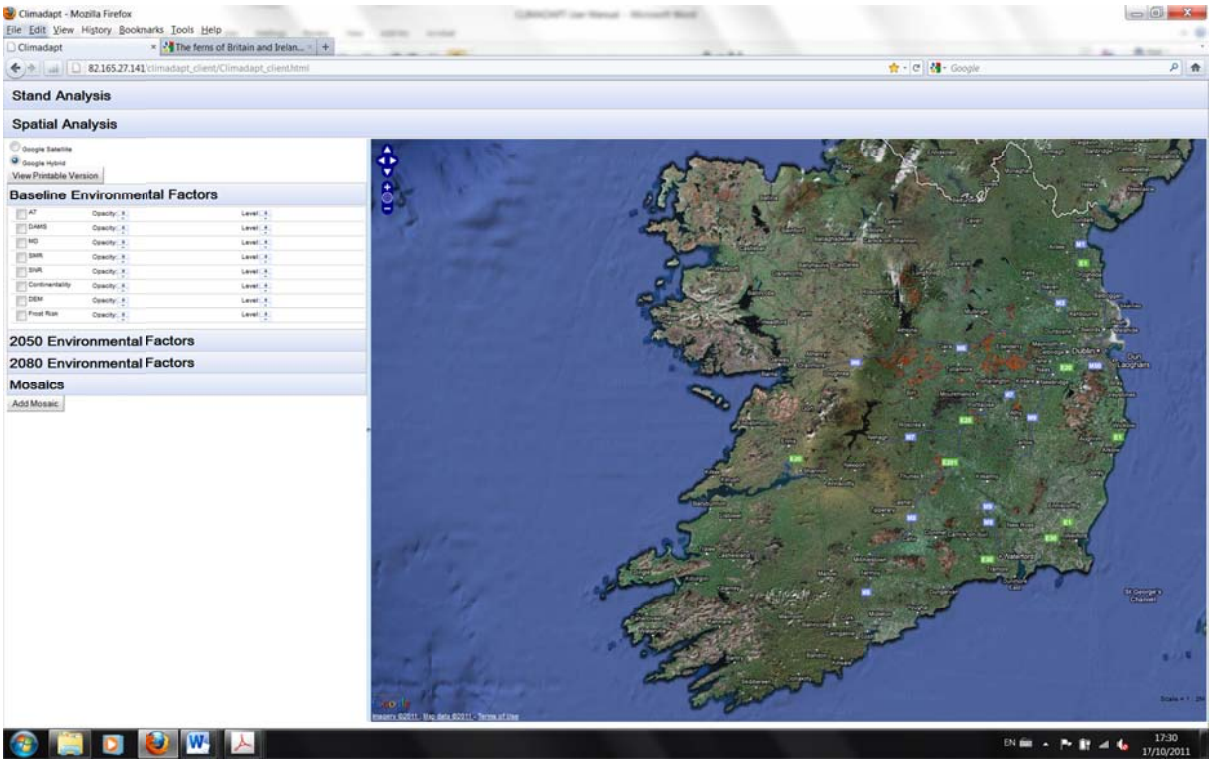
Section 3: Spatial analysis

3.1 Navigating to the area of interest for your study

Click on ,<Spatial analysis> at bottom left of screen



The following should appear……



a) Select on Google hybrid to show roads and towns (not all town and viliges are shown, but these can be used as a guide to locate your site)

b) Adjust scale and location to clearly show your area of interest.(red circle)

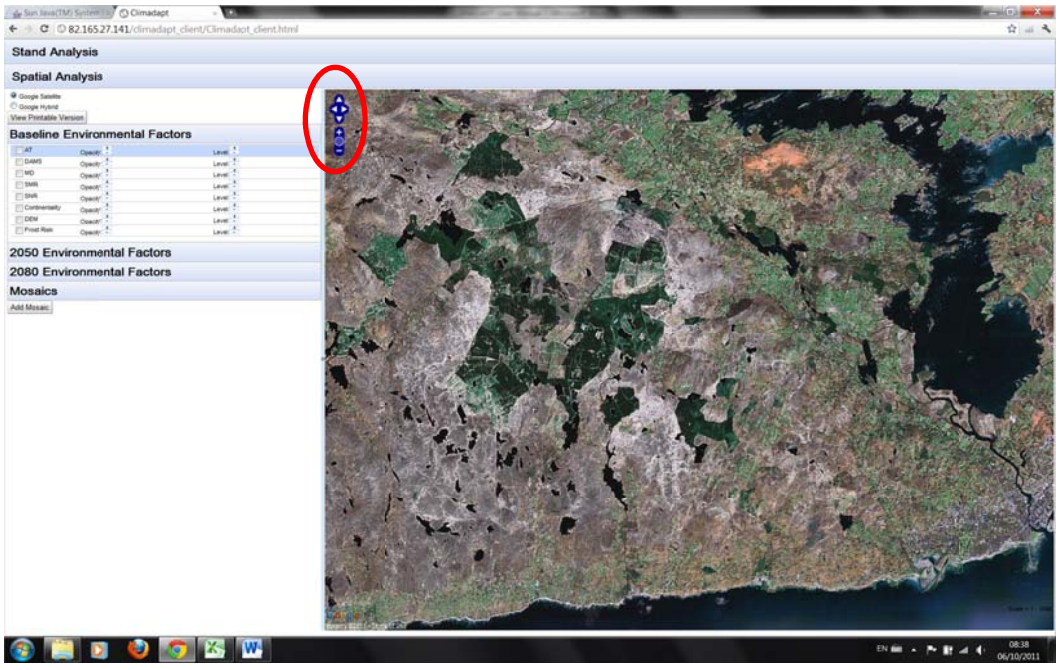


Figure 22: Cloosh area has been selected again!

- Select required environmental factors. For example select frost risk by clicking on the box under baseline environmental factors.
  Note environmental factors under future climate change scenarios up to 2080 can also be observed in the same way)

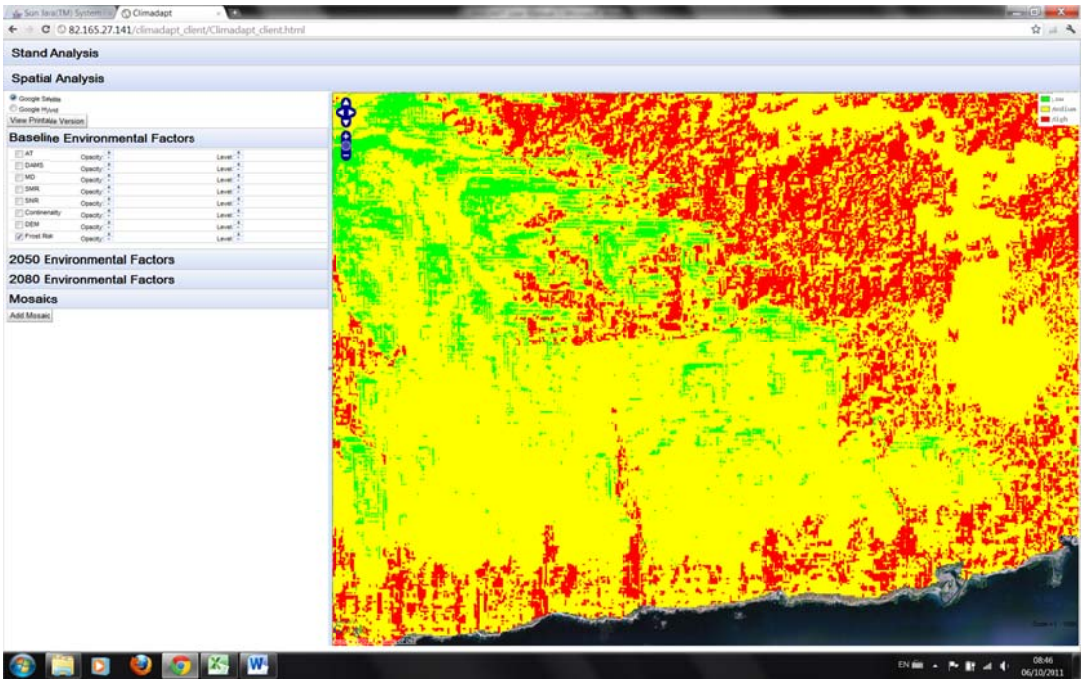


Figure 23: Frost risk zones in the Cloosh region (red is high, green is low)

- The opacity of the GIS layer can be reduced by clicking the '-' bar next to frost risk (figure 24). This should enable you to see the site with overlaying GIS information. In this example the frost risk would be medium (see legend yellow value is 2, 1is low, 3 is high (red))

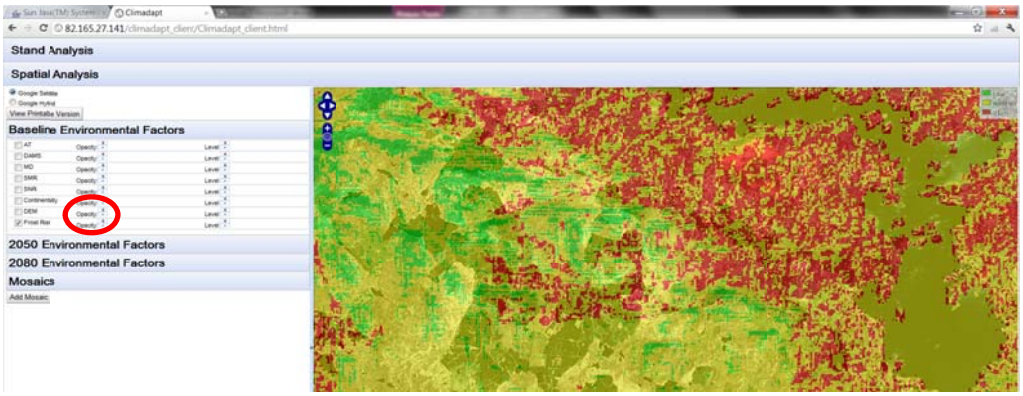


Figure 24: Changing the opacity to see your area or forest of interest

- Alternatively the warmth index can be selected by, clicking off frost risk and selecting **AT** (accumulated temperature above 5 day degrees) this is a warmth index, where higher values represent warmed climates where productivity would generally be higher. In this example the site AT value is 1750 to 1800 day degrees under the current climate (Figure 25).

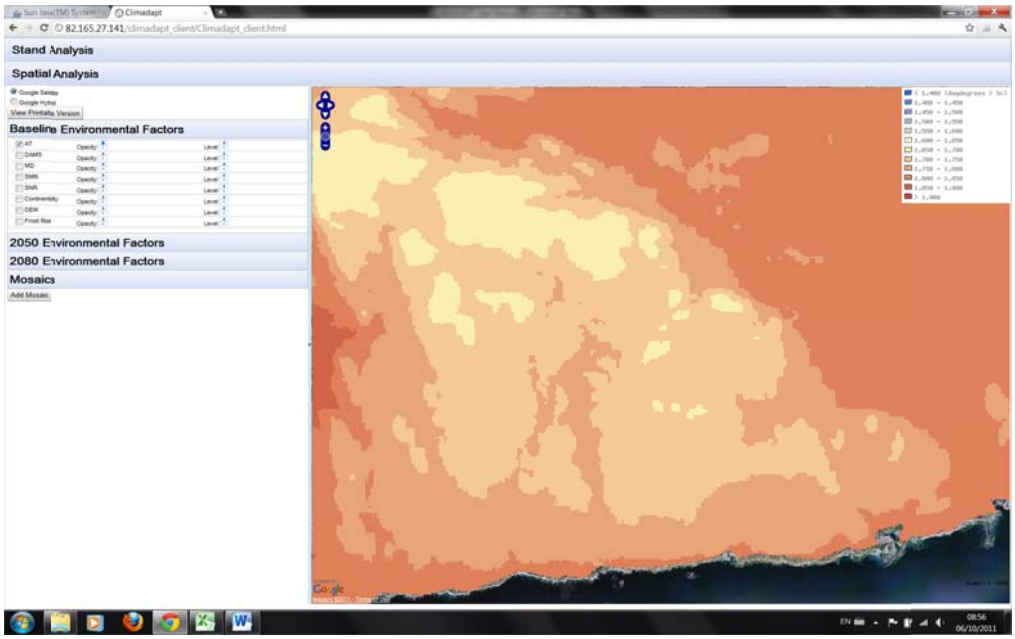


Figure 25: AT for regions surrounding Cloosh forest

- Another site factor with influenced productivity and yield would be continentality (a measure of distance from the ocean). For example inland regions would generally be cooler with more frequent frosts. You may have noticed the scale of the map in figure 26 has been reduced to show how continetality varies across the whole country.

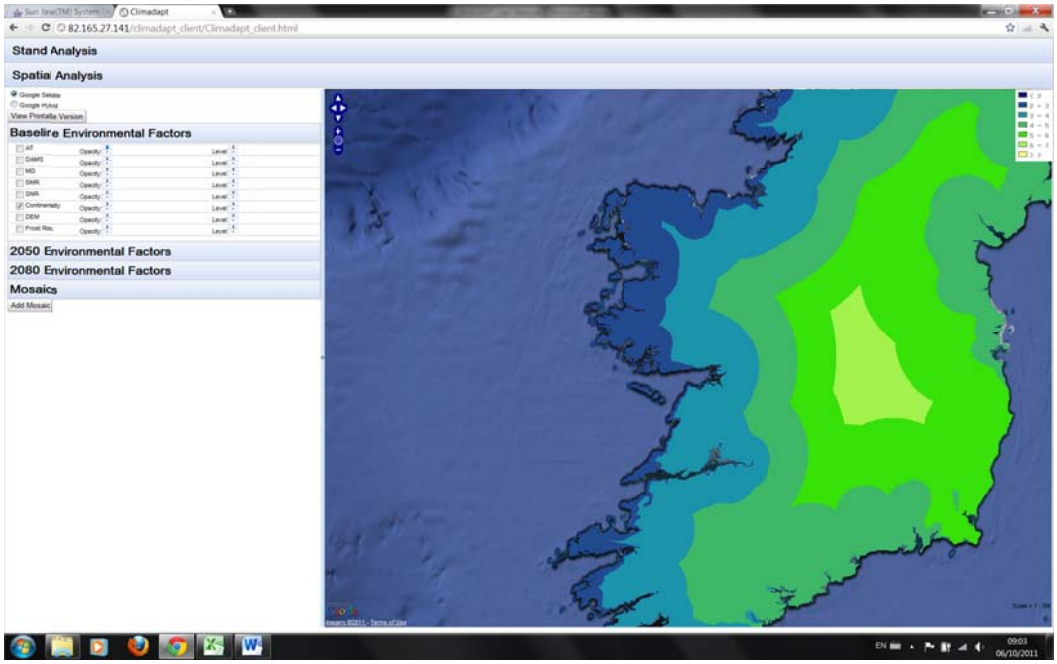


Figure 26: Continetality AT for regions surrounding Cloosh forest

- Any number of environmental factors can be investigated for regions or sites for current and future climates.

3.2 Analysis of future climate changes

If you would like to see future climate click on <2050 Environmental Factors> or <2080 Environmental Factors> the same selection boxes will appear.

Note: the 2080 scenario does not have the b1 scenario because these simulations were not available form Met Eireann at the time the project was completed.

- For example the two maps of the Galway region below show the change in AT

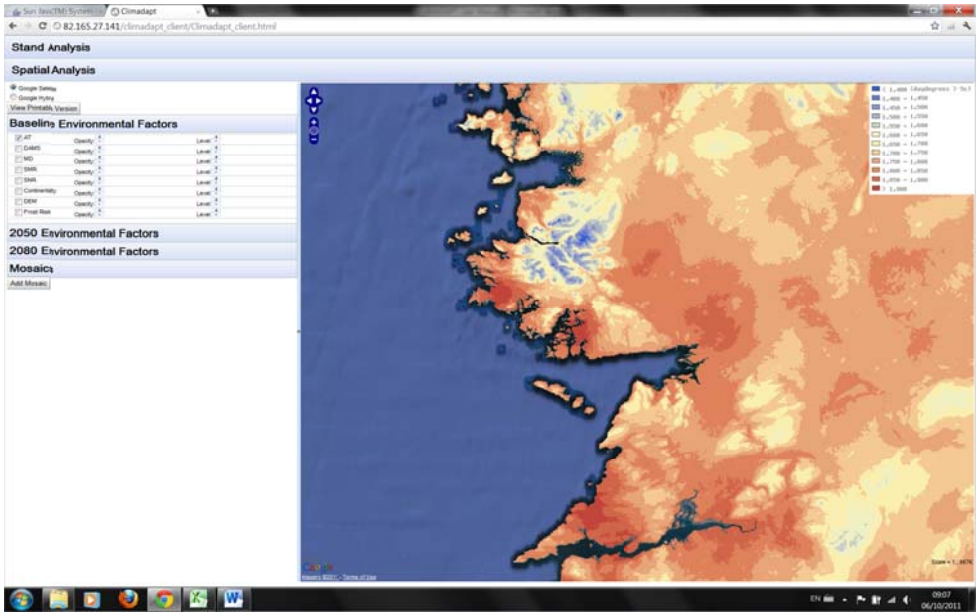


Figure 27a: AT for Galway under the current climate

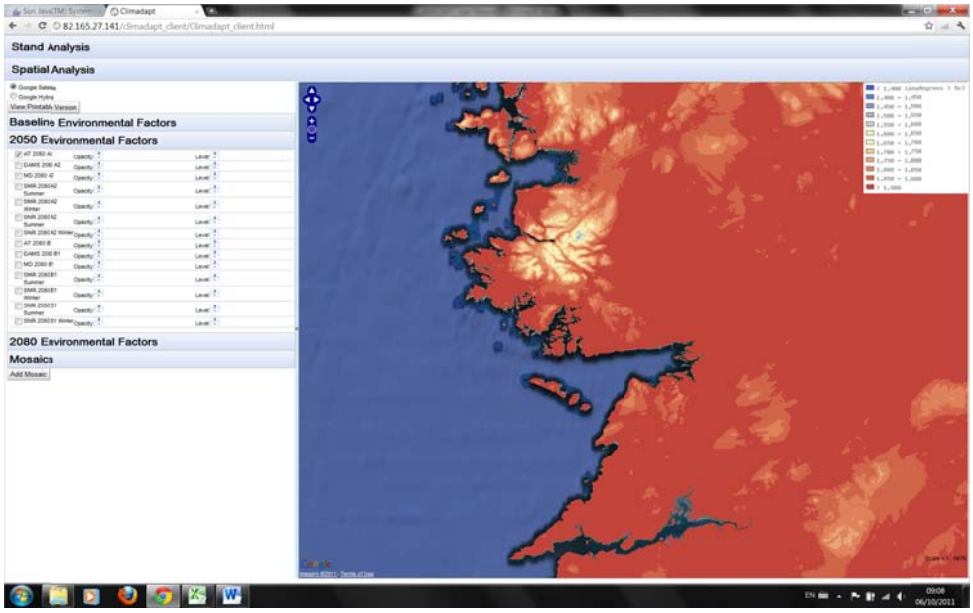


Figure 27b: AT for Galway under the A2 climatechange by 2050

In this example you can clearly see AT, and warm index will increase, but there is not always good news…….

Figure 28 shows how soil moisture deficits will increase in the SE regions of the country:

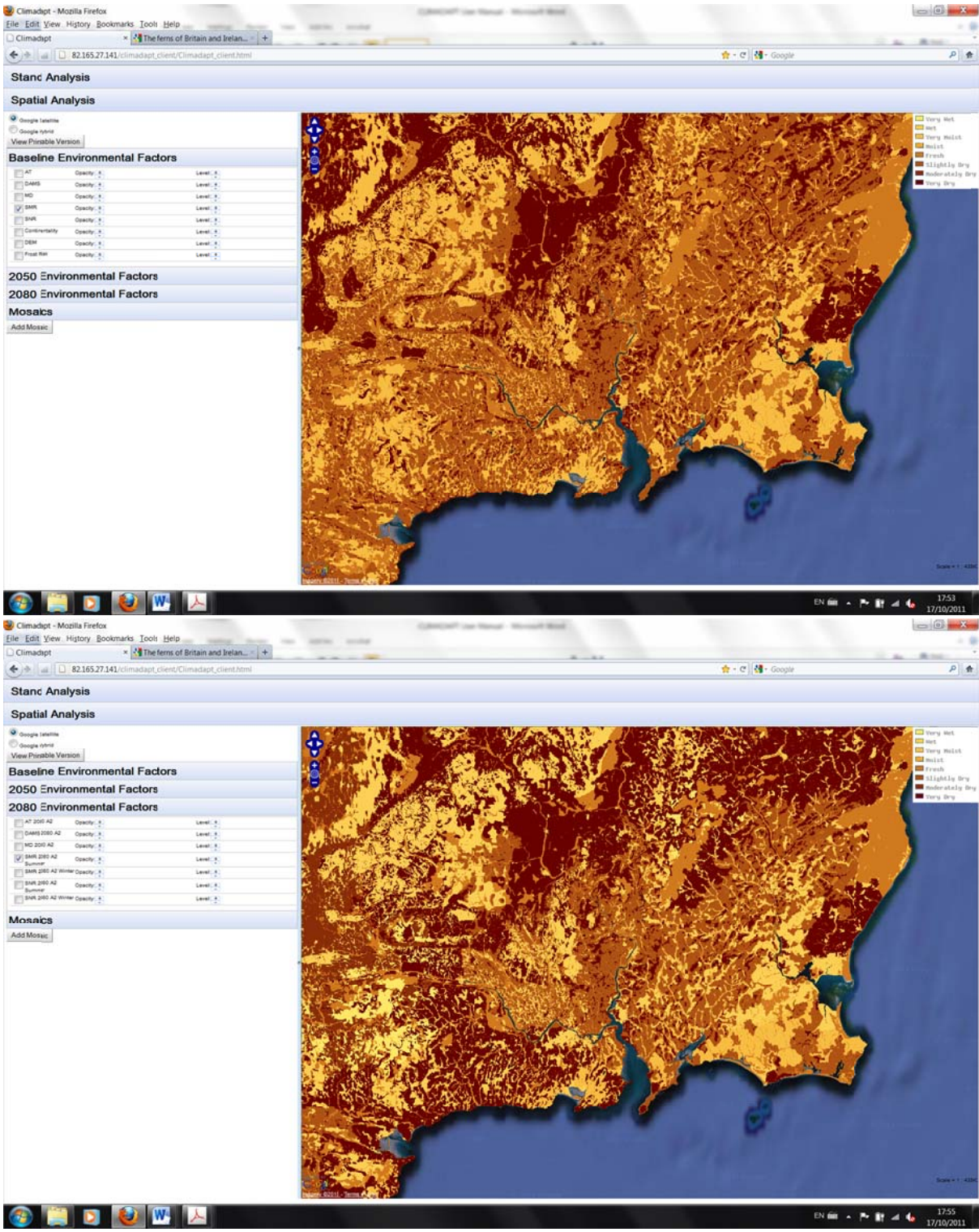
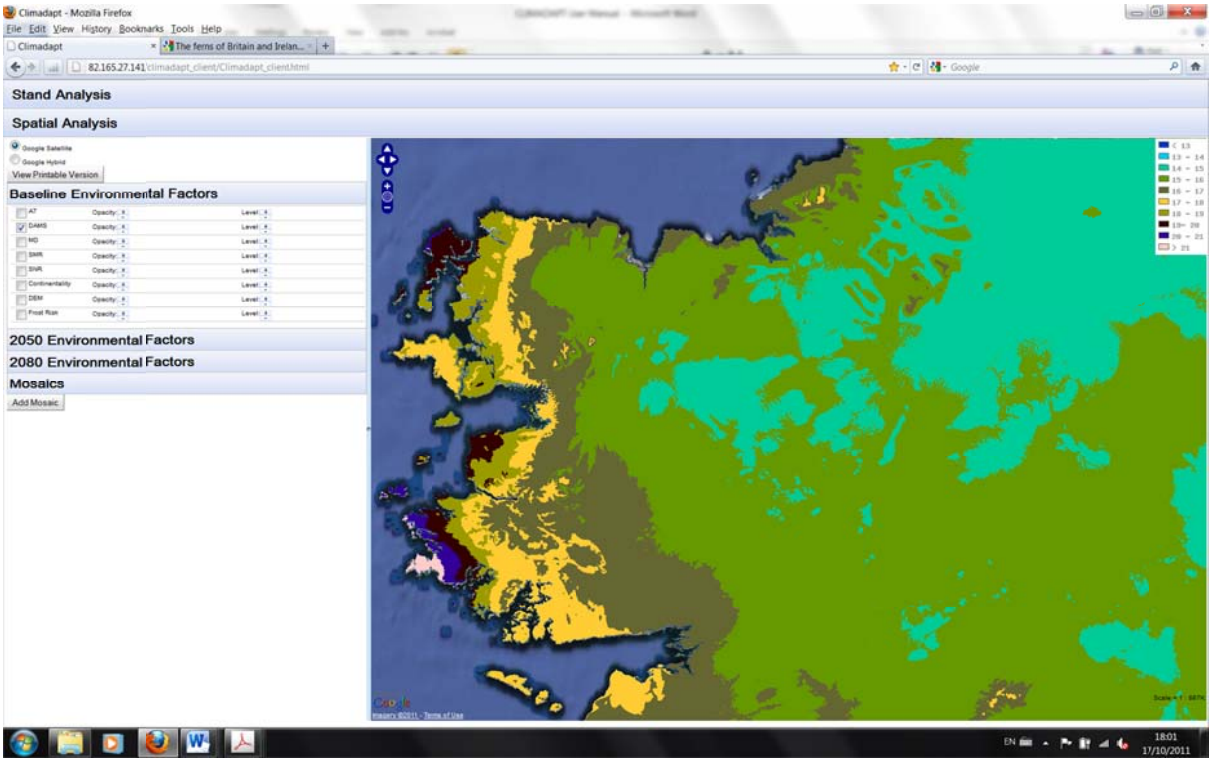
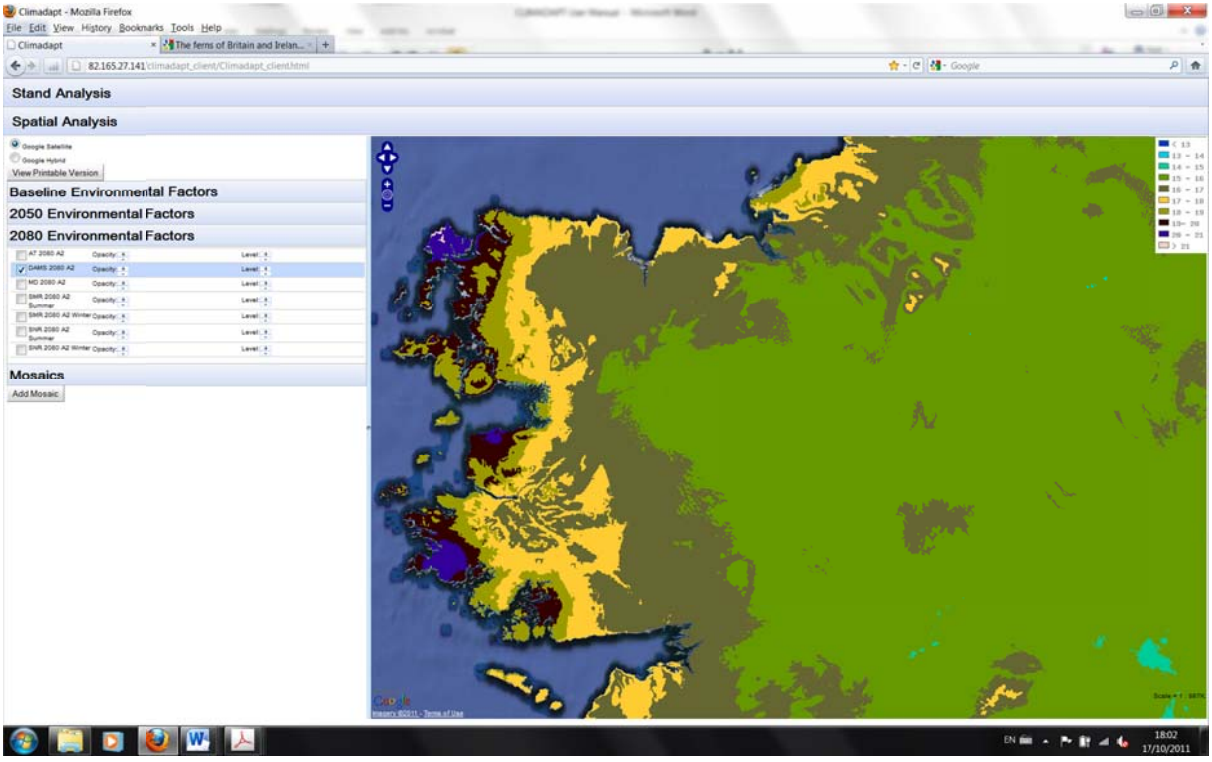


Figure 28: SMD under current climate compared to 2080 (bottom panel)

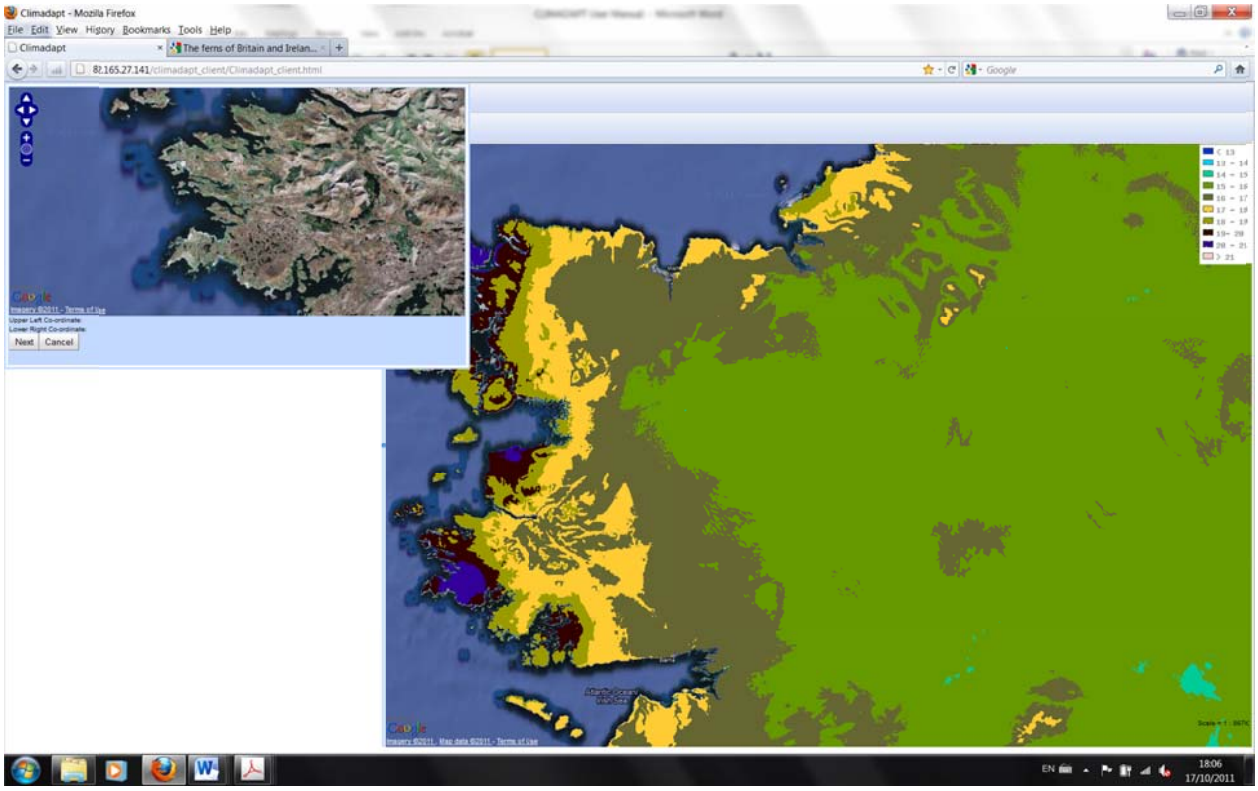
Figure 29 shows how exposure and windiness will increase in the Mayo Donegal region under future climate change scenarios.

- 

- 

3.3 Using the mosaic function

This function is use full if you wish to display the environmental facto together with a satellite map of the same area. To do this click <Add mosaics> and explore to the region of interest.



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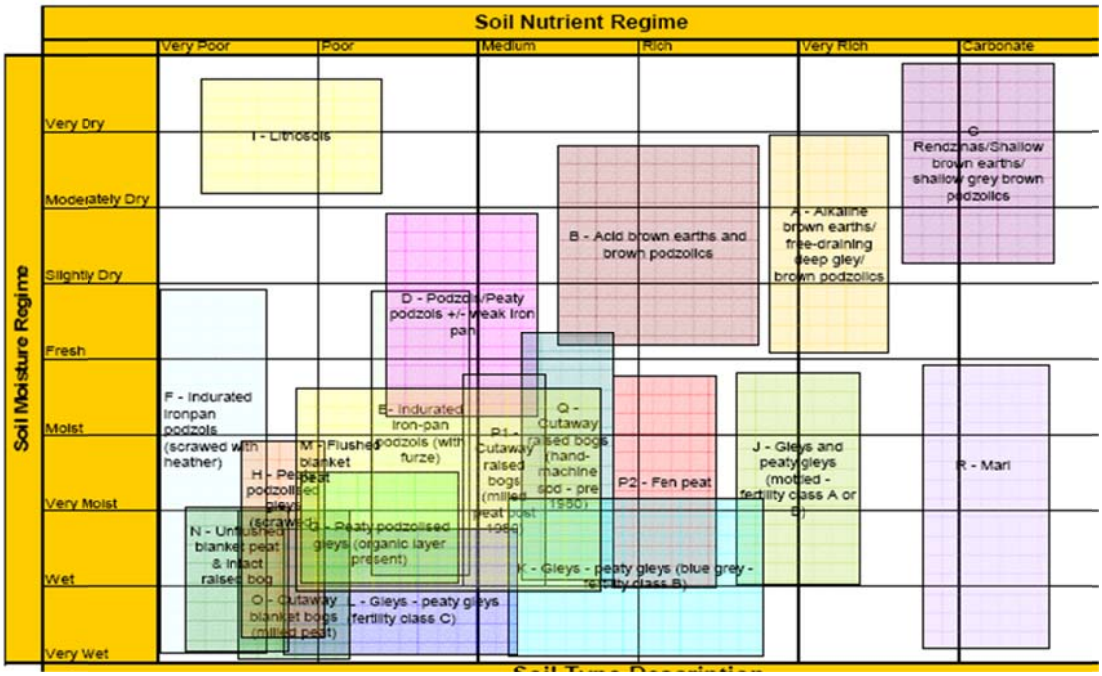
Appendices

Appendix A: Default soils characteristics

Figure 1: A Guide for soil moisture classification Soil moisture regime (SMR) can be very dry to slightly = well drained, fresh to very moist = moderate and wet to very wet = poorly drained. Soil nutrient can vary from carbonate to ver poor depending on the soil type identified using the indicative soil map.



Appendix 2: Some guides to soils identification (taken form the NFI)

Each soil group is briefly described in the following section. The photographs labelled **©Teagasc, 2007** were reproduced with the permission of Teagasc from a presentation to the Forest Service (Radford,2004). Photographs labelled **©Coford, 2007** were reproduced with the permission of COFORD from *AGuide to forest Tree Species Selection and Silviculture in Ireland* (Horgan *et al.*, 2003).

Brown earth

Relatively mature, well-drained mineral soils, derived from parent materials of acidic or basic status (Figures 2-4).These soils possess a rather uniform profile with little differentiation in horizons and no removal and deposition of materials such as iron oxides, humus or clay, although constituents such as calcium and magnesium may be leached to some extent. They occupy approximately 13% of the land area of Ireland.

Figure 2. Brown earth.

Figure 3.Acid brown earth.

Figure 4. High base brown earth.

Grey brown podzolic

These well-drained mineral soils are similar in many respects to the brown earths, except that clay has been translocated from the surface to a sub-surface layer (horizon) (Figure 5).They are usually

formed from glacial drift of predominantly limestone composition and have a medium to high base saturation status. They occupy approximately 24% of the land area of the country.

Figure 5. Grey brown podzolic (left) and Grey brown podzolic (right).

Brown podzolic

Well-drained, acid mineral soils, derived mainly from acidic parent materials such as shale, granite or sandstone (Figure 6). Located on hills and rolling lowland. They are formed under the influence of the podzolisation process, subject to some leaching. Due to the presence of iron oxides the horizon has a reddish-brown colour. This group occupies approximately 12% of the land area of the country.

Figure 6. Brown podzolic.

Podzol

These soils are subject to intense leaching of minerals, particularly iron and aluminium, and are formed from acidic parent materials (Figure 7). They have a distinct sequence of horizons, with a subsurface layer of removal, the A2 horizon and subsurface layer of accumulation, B horizon. Due to severe leaching of iron and cementation, some podzols may develop a thin impervious 'iron pan' in theB horizon. They may have a peaty surface layer of less than 30 cm drained or 45 cm undrained and are located on mountain and hill land, where the high rainfall is a major factor in their development. They occupy approximately 8% of the land of the country.

Figure 7. Podzol (left) and Peaty podzol (right).

Gley

This group contains soils in which the effects of drainage impedance dominate (Figure 8). They develop under conditions of permanent or intermittent waterlogging. The mineral horizons of Gleys are grey or blue-grey in colour, with distinct rusty mottling frequently evident. Rooting depth is usually limited, aeration is poor and rate of organic matter decomposition is slow. The impeded condition may be due to a high water level, seepage or springs, or it may be due to the impervious nature of the parent material. Gleys occupy approximately 22% of the land area of Ireland.

Figure 8. Gley.

Rendzina

These are well-drained, shallow mineral soils (Figure 9).They are very dark in colour, with a high lime content. Derived from limestone bedrock, or limestone sands and gravels such as eskers, they are less than 50 cm in depth.

Figure 9. Rendzinas. Figure 35. Rendzina.

Peats

For an area to be classified as peat, the peat depth has to be greater than 30 cm on drained and 45 cm on undrained land. Peats are divided into two basic groups:

Basin peat

Basin peat consists of fen peat and raised bog.Fen peat originally formed under the influence of base rich ground water in shallow lakebeds and depressions in the landscape. It is usually alkaline in its lower layers but as it develops, the upper layers become more acidic and the vegetation changes from one dominated by *Phragmites* and *Carex* species to one of *Sphagnum* and *Calluna* species, resulting in raised bog.

Blanket peat

Blanket peat occurs in wet, cold and acid conditions in elevated areas and at lower elevations along the western seaboard. Blanket peat usually extends over the entire landscape, covering the hills and valleys. Its vegetation is usually dominated by acid-loving plants, such as *Sphagnum, Calluna,*

Tricophorum, Eriophorum and *Molinia* species. When it occurs at elevations greater than 150 m it is described as 'high level'; below this, it is described as 'low level' blanket peat.

Regosol

This group consists of mineral soils, which are immature and show little distinct horizon development (Figure 10). They occur in low lying at areas along river courses, lake-beds or at mouths of river estuaries. The texture varies from sands to clays, drainage ranges from excessive to poor. These may be acid or alkaline depending on the source of deposits.

*Figure 10. Regosol***.**

Sand

Soils occurring in this group are found in coastal regions and are characterised by the high percentage (>90%) of sand content (Figure 11).These soils have very little horizon differentiation. Due to the absence of clay and silt particles, these soils have poor nutrient and moisture retention capacity.

Figure 11. Sand.

Lithosol

These are very shallow and stony mineral soils, usually overlying solid or shattered bedrock (Figure 12). Located mainly at higher elevations where they are associated with podzols**.** These soils are frequently characterised by outcropping rock and may occur on steep slopes.

Figure 12 Lithosols