<u>THE ALBEDO EFFECT AND ITS EFFECT ON AFFORESTATION CARBON OFFSET PROJECTS</u>

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Recent research emerging from the US suggests that forests' ability in boreal and temperate zones (especially with regard to afforestation projects) to sequester CO2 and mitigate the effects of climate change is exaggerated using a "carbon only" approach. In some circumstances location, land-use change and the effects these factors have on surface albedo, can result in afforestation projects being counter-productive and even lead to localised global warming due to positive radiative forcing. This may result in the abandonment or limitation of afforestation projects in boreal and temperate zones.

Current thinking here in the UK and in Europe is that afforestation is "good for the environment" in terms of locking up carbon as a forest sink. Policies are being promoted to advocate the efficacy of forestry in climate change mitigation. A voluntary forest carbon market is developing in the UK and forest carbon afforestation offset projects are being launched and measured against the UK Forestry Commission's Code of Good Practice for Forestry Offsets for UK-based Forest Carbon Management Projects due to be released in April 2010, which will become the industry standard. The voluntary forest carbon market will allow companies, for example, to deliver on their Corporate Social Responsibility strategies (CSR) and offset some of their carbon emissions since trees are perceived to be capable of mitigating climate change via carbon sequestration.

Afforestation projects in boreal and temperate zones may be a cause of some concern as these are the projects perceived to be the most likely forest types to provide carbon offset credits to clients looking to reduce their "carbon footprint", and yet recent research published in the USA suggests that forests' ability in temperate zones (especially afforestation projects) to effectively sequester CO2 and mitigate the effects of climate change may be reduced and even eliminated due to location, land-use change and the effects these factors can have on surface albedo.

The albedo of an object is the fraction of incident solar radiation it reflects. It is mostly determined by the colour and texture of a surface. Land-use change is one variable influencing global albedo, which in turn can influence climate (IPCC 2007). The climatic impacts of carbon sequestration, surface albedo and other processes can be expressed in terms of radiative forcing, defined as the net change in global irradiance due to changes in external climate drivers (IPCC 2007).

There is growing body of research that suggests climatic impacts of forests are not limited to atmospheric greenhouse gas concentrations alone. The premise is that because forests are generally darker than bare agricultural land, they absorb relatively more solar radiation, which may exert a local warming influence as a result of positive radiative forcing due to albedo (Thompson et al. 2009). Replacing snow with a surface that absorbs more sunlight, such as evergreen spruce or pine canopy, warms the area at spatial scales of hundreds or even thousands of kilometers (Jackson et al. 2008).

In an article entitled "The Albedo Effect and Forest Carbon Offset Design" published in the December 2009 edition of The Society of American Foresters, Journal of Forestry, Thompson et al. suggest that albedo-related climatic changes stemming from land-use change may diminish or counteract the climatic benefits of carbon sequestration. The authors suggest that a "carbon only" accounting approach that ignores albedo impacts, can significantly overestimate the climatic benefit of forest carbon offsets, in particular, from afforestation. They advocate a more targeted geographical approach and that forest offset design move toward "carbon-equivalent" accounting to incorporate the albedo factor, location and biogeophysical factors such as roughness or unevenness of the vegetation canopy and evapotranspiration.

For instance, in tropical regions, afforestation may be positively beneficial in sequestering carbon since it can lead to cloud formations resulting in global cooling. In boreal regions, however, low surface albedo exerts a positive climatic forcing that "may exceed the negative forcing from sequestration" (Thompson et al. 2009). The countervailing response is especially evident in snowy regions where in the absence of forest cover, the land stays white and reflects sunlight for much of the year resulting in temperature cooling (Betts 2000). Reduction in surface albedo from forestation may therefore exert a release of carbon just like that of “wildfire or harvest" (Thompson et al. 2009).

Because biogeophysical processes act more immediately on climate than does the carbon cycle, Bonan (2008) suggests that for some boreal afforestation projects, near-term warming can be expected before sequestration benefits materialise. Van Minnen et al. (2008) suggest that plantations should not be established at high latitudes if climate mitigation is the sole objective. Schaeffer et al. (2007) question the efficacy of extratropical carbon plantations as a mitigation strategy. Betts et al. (2007) and Gibbard et al. (2005) suggest that carbon plantations outside of the tropics could be less effective than expected or even counter-productive. South (2008) suggests that foresters have not fully considered the albedo effect and questions the efficacy of temperate afforestation efforts. Jackson et al. (2008) state that ignoring biophysical interactions could result in millions of dollars being invested in some mitigation projects providing little climate benefit or, worse still, could be counter-productive. Overall, such biophysical changes can affect local to regional climate much more than the accompanying carbon sequestration does – and sometimes in a conflicting way (Jackson et al. 2008).

What about the UK and Europe? The effects of albedo on afforestation offset projects certainly in the UK have not been fully quantified mainly because of a lack of research in this area. A carbon only approach seems to be the *“concept du jour”*. However, in a study area in southern Europe, Schaefer and Bird (2009) show that under specific circumstances, afforestation/reforestation measures may not automatically have positive impacts in a global warming context because the cooling effect of most of the carbon sequestered is neutralized by the warming effect of albedo changes. In the study albedo and carbon sequestration modeling results are linked to determine the combined radiative forcing balance. The conclusion is that accounting based exclusively on GHG units does not, in the case of land use change, reflect the entire picture. The authors recommend that in future global warming impacts of land use systems and biogenic products (e.g. solid biomass, liquid biofuels) should be studied using life cycle assessments (LCA) and should include these additional—non-GHG effects—on climate change (Schaefer and Bird, 2009). Experts in the US align with this view and suggest that current "carbon-only" approaches, which ignore the albedo effect, are “incomplete” (Schaeffer et al. 2007), give a "false impression" (Betts et al. 2007), are "inadequate" and limit their ability to accurately portray the climatic impacts of afforestation.

Marland et al. (2003) recommend climatic mitigation policies focus on radiative forcing rather than greenhouse gas concentrations and suggest greater flexibility be applied to take into account regional and other factors as outlined above. Thus accounting calculations could be adjusted for albedo-related climatic impacts to express an offset's true contribution in terms of "carbon equivalent". Betts (2000) developed a methodology along these lines premised on the notion of radiative forcing associated with albedo changes in terms of "equivalent carbon flux". The net equivalent carbon stock change (NESC) due to afforestation is therefore described as the sequestration potential (SP) less albedo-related equivalent emissions produced by shortwave forcing (EESF). Therefore;

$NESC = SP - EESF$ (Thompson et al., 2009)

The calculations of Betts (2000) suggest that boreal and temperate afforestation can result in significant quantities of albedo-related equivalent emissions over the course of a single management rotation of forests. In Canada, estimated equivalent emissions ranged from 60 to 110 tonnes of carbon per hectare per year which was greater than the mean carbon sink potential of 60 tonnes of carbon per hectare per year. EESF values in the Northern United States reached 80 tonnes carbon per hectare per year and in the Rocky Mountains exceeded 100 tonnes carbon per hectare per year.

The ratio NESC/SP expresses the relative efficiency of the carbon offset in terms of Net Equivalent Sequestration (NES). The NES amounted to 70-80% of actual sequestration in the USA. In British Columbia the NES dropped to 60% of actual sequestration and in the rest of Canada dropped further to minus 50%.

Our climate in the UK is temperate and similar to the US west-coast. Afforestation and restocking in the uplands in the commercial forestry sector is usually carried out by planting exotic conifers such as Sitka spruce, Douglas fir, western red cedar etc. with a 10-15% broadleaved component and/or open ground. Such conditions could be classified, in theory, as having low albedo. If we were to apply the findings of US research and relate them to the UK situation, conifer plantations may theoretically produce "positive radiative forcing" leading to localised warming here especially in the uplands. This view is controversial in the UK and certainly runs contrary to most people’s and the forest industry’s perceptions, although it has to be said that research under UK conditions to measure albedo-related factors and the influence of biogeophysical factors such as evaporative cooling in relation to forest carbon sequestration, as far as is known, has yet to be fully carried out. Bonan (2008) states the evaporative effect of temperate forests remains unclear and the net climate forcing is not known. A number of climate model studies suggest that replacing forests with agriculture or grasslands in temperate regions cools surface air temperatures. Other studies show the opposite-that temperate forests cool the air compared with grasslands and croplands (Jackson et. al. 2008).

Thompson et al. (2009) recommend that there is a possibility of managing for the albedo effect via species selection and planting more broadleaves and deciduous conifers such as *larix* (larch) that may provide an albedo benefit by increasing snow exposure in winter. Other ways to manage and mitigate the effects of albedo could include silvicultural prescriptions such as Continuous Cover Forestry (CCF), agroforestry, extending the rotation age, which can significantly impact carbon storage over time (Harmon and Marks 2002) and managing for increased expected carbon density by reducing the risk of wildfire by thinning and other disturbances such as insect outbreak, thereby avoiding emissions as a result of Reduced Emissions from Deforestation and Degradation (REDD). For example, Canadian forests are predicted to be a net source of carbon emissions for the next couple of decades because of fire and insect outbreak (Kurtz et al. 2008). The environmental benefits of using wood substitution could also mitigate the effects of positive radiative forcing.

In conclusion, Thompson et al. (2009) suggest that after discounting for risk, leakage and possible countervailing albedo effects, the net equivalent carbon gain associated with some offset projects may be "significantly diminished". This may result in the abandonment or limitation of afforestation in boreal and temperate regions. The authors stress that in boreal regions, afforestation should not be permitted as an offset type. Likewise, high altitude temperate afforestation "should be avoided", especially in snowy regions and that forests' full range of climatic impacts should be accounted for in offset design. Offset efforts in boreal and temperate regions should be directed towards increasing onsite carbon density, reducing the risk of forest degradation and promoting the benefits of wood substitution. The latter benefits are also highlighted in the Read Report entitled "Combating Climate Change - A Role for UK Forests" (2009).

It appears that in the light of the research findings from the US and the FC report, as far as afforestation projects within temperate regions is concerned, it is the positive contribution forests make towards emissions abatement and wood product substitution that needs to be measured against the countervailing effects of albedo. More research is needed in this area. On this basis, rather than on the basis of forests' abilities to sequester CO_2, policy-makers and foresters are in a more informed position to be able to determine whether afforestation projects, particularly in the uplands, can have a place in combating climate change or not.

Finally, Thompson et al. (2009), go on to recommend that it is in tropical regions where afforestation offset efforts be directed, as it is here where there is a clear and conclusive environmental benefit due to evaporative cooling. Based on decades of research in carbon sequestration and biophysics, Jackson et al. (2008) suggest that avoided deforestation, forest restoration and afforestation in the tropics provide the greatest value for slowing climate change. Thus purchasing forest carbon offsets from tropical countries is the most environmentally beneficial if one were to enter the forest carbon offset market. This is in addition to other available mitigation options such as reducing emissions via REDD, which is considered to be the least costly (Stern 2006). In the near-term, forest-based mitigation efforts should be targeted where they can be most effective.

There is little detailed information and methodology in the UK Code of Good Practice about how carbon sequestration values are to be calculated and certainly no mention of the role of albedo in calculating NES to accurately determine the net amount of carbon sequestration arising from UK afforestation projects. The current "carbon only" approach appears limited within the temperate geographical context. Calculations and methodology need to be adjusted to include albedo-related climatic impacts and biophysical factors. It is recommended further research, to develop a more robust "carbon equivalent" approach for measuring an offset's true net worth is required, if afforestation projects in the UK are to have any credibility and validity in the emerging Voluntary Over-the-Counter (OTC) forest carbon offsets market.

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