Perennial Rhizomatous Grasses as a Source of Biomass Energy – the ideal energy crops?

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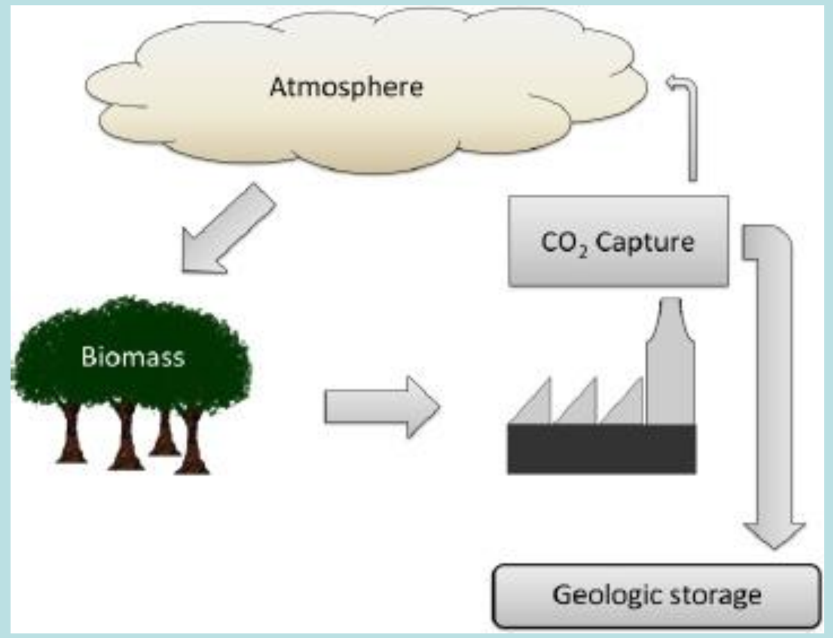
Introduction

Given the continuing increase in atmospheric CO_2 concentration at roughly 2 ppm y^{-1} and the impact on global temperature increase, strategies for atmospheric CO_2 removal (CDR) are being considered for climate change mitigation. One category of CDR is terrestrial biological CO_2 removal as it increases terrestrial carbon uptake and storage through higher plant biomass productivity and carbon residence times. Projected global requirements for biomass feedstock and estimates of biomass production suggest that by the middle of this century there will be significant shortfalls in utilisable supply. The question is whether policies to widely promote the production of biomass are justified given the uncertainties about how much biomass can be produced and the impact that this has on the availability of land and water, particularly for food production, and the impact on biodiversity conservation. There is clearly a need for more reliable bottom up assessments, supported by empirical studies and experiments, to better inform the debate.
One major debate continues to revolve around the selection of the biomass source, its sustainability and productivity and how it could be utilised. We review some of these issues here.

Utilising plant biomass

Bio-Energy with Carbon Capture and Storage (BECCS) is one of the most discussed processes for terrestrial biological removal. BECCS has been included in many integrated assessment models (IAMs) to compensate for overshooting safe levels of atmospheric CO_2. In addition, it is currently the only negative emission technology (NET) explicitly included in IPCC scenarios. The BECCS concept is fairly straightforward. Biomass captures CO_2 during growth and stores it in the form of organic material, such as trunks, stems, leaves, roots, etc. The biomass is subsequently burned in a power plant (or converted in another energy conversion plant), producing electricity (or another energy carrier). The CO_2 that is produced during biomass combustion is captured and stored underground, thereby effectively removing it from the atmosphere. As indicated, the use of biomass for BECCS is not limited to the power sector, but can also be integrated in other, biofuel, or biogas production.



The BECCS carbon cycle

Beneficial characteristics of PRGs

Beneficial characteristics of annual, short rotation forestry and PRG bioenergy crops

Crop characteristics	Annuals	Short-rotation forestry	PRGs (*Miscanthus*)
C_4 photosynthesis	✓		✓
Long canopy duration		✓	✓
Perennial		✓	✓
Recycles nutrients to roots			✓
Stores carbon in soil		✓	✓
High output/input energy ratios			✓
Dry down in the field (Low drying costs)			✓
High water use efficiency	✓		✓
Low mineral content at harvest (clean burning)		✓	✓
High biodiversity			✓
Non-invasive	NA	✓	✓
Few pests and diseases			✓
Good winter standing (low storage costs)		✓	✓
Use existing farm equipment for planting and harvesting	✓		✓

Perennial rhizomatous grasses (PRGs) have physiological and morphological characteristics that mean they produce large amounts of biomass, which can be harvested on an annual basis for several years. The most intensively studied PRG is *Miscanthus*.

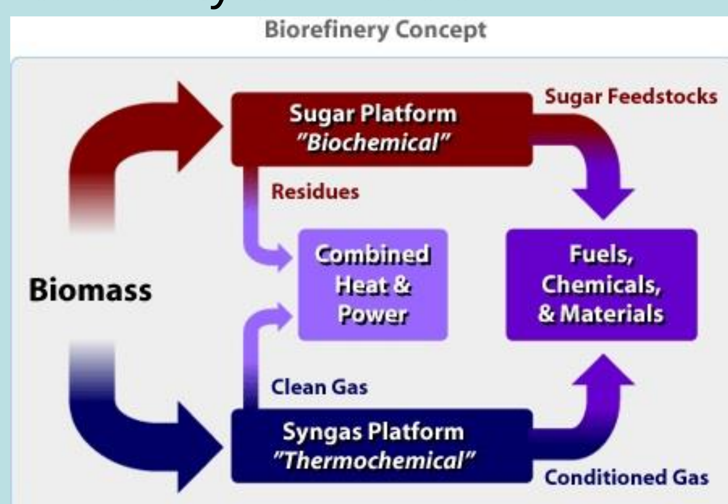

Productivity trial of *Miscanthus* genotypes in Wales
(Courtesy of Jon McCalmont, Aberystwyth)

Beneficial characteristics of PRGs

Yield trials of PRG crops have been carried out in a number of locations in North America and Europe (Lewandowski et al., 2000, Heaton et al., 2004). Yields vary with climate, soil conditions, levels of fertiliser application and water availability. The highest recorded annual yields for *Miscanthus* are close to 25 Mg ha^{-1} and these are normally achieved with low levels of fertiliser application. In recent years a number of crop models have been developed to provide reliable predictions of yield under a wide range of climatic conditions (Nair et al., 2012).
PRG crops have the potential for carbon sequestration in soils. Firstly, perennial plants allocate high proportions of the assimilated carbon belowground as a carbon reservoir for growth in the spring and the perennial nature also reduces tillage to initial planting and crop discontinuation, significantly reducing soil disruption and therefore increasing soli organic carbon (SOC) stability. Secondly, PRGs are typically harvested in spring after the above ground biomass has senesced to minimise moisture content at time of harvest and the high pre-harvest losses of leaves increases the input of this carbon to the soil. Thirdly, because PRGs receives little or no N fertilizer this results in a high C:N ratios in the soil which leads to a slower decomposition of the plant residues. Stabilization of soil organic carbon for long term sequestration occurs through a number of processes which leads to the formation of more recalcitrant soil fractions.

Competition for plant biomass

The competition for plant biomass is likely to become more intense in the future as the biorefinery concept takes hold. The biorefinery process produces both energy and high value products, The expanding bioeconomy must be based on sustainable practices to ensure unequivocal carbon savings and to avoid any other detrimental environmental, social or economic impacts. It is also essential to recognise and safeguard the role of biomass and biomass based products as long term carbon sinks. It is increasingly clear sustainably scaling up the bioeconomy is possible, given smart agricultural practices, better use of rural and urban waste, and proper policies. The second generation perennial biomass crops (PBCs), such as *Miscanthus,* offer opportunities for supplying viable bioeconomies at an international scale while at the same time improving environmental conditions through both increased soil carbon sequestration, soil fertility and biodiversity, and reduced nitrate leaching, soil erosion and demand for agrochemicals. Clearly, the development of a bioeconomy, based on the development of biorefineries, will provide strong competition for biomass feedstocks and could threaten the viability of BECCS.



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