The effect of energy crops on floodplain flows

Under the Renewable Energy Strategy the UK aims to achieve 15% of its energy needs from renewable sources by 2020, with 30% of the renewable energy target coming from biomass. Farmers are being encouraged through the Energy Crops Scheme (ECS) to plant energy crops such as Miscanthus or Short Rotation Coppice (SRC), such as Willow, Poplar or Ash, in suitable locations. However, there is still a general lack of understanding of the potential impacts that dense plantings of these crops on the floodplain might have on the flood dynamics both upstream of downstream.

The Environment Agency commissioned a short term modelling study to explore a range of possible energy crop plantation configurations on the floodplain (within Flood Zone 3) and how these might influence the 100 year flood water levels, flow pathways and velocities, and in-channel hydrographs. Changes to any of these factors will determine how the energy crop plantations might influence the flood risk both locality and further afield. In particular, both the local and upstream/downstream effects were analysed to provide some evidence on the spatial extent of any change when compared to a baseline floodplain condition covered by an arable crop, namely winter wheat.

The findings from this study should be treated as providing supplementary material to the existing Environment Agency guidelines entitled – Flood Risk Management: Woodland, tree planting and flood risk.

Hydraulic impacts of energy crops on floodplain flows

Vegetation cover on the floodplain can have greater or lesser impact on the propagation of flood water downstream and also the potential for flood attenuation, depending on the degree of hydraulic resistance of the cover to flow. The physical characteristics of floodplain vegetation can be represented in hydraulic models by roughness parameters (such as the Manning's n roughness coefficient) and the impact on flooding dynamics can then be explored.

The very dense nature of the vegetative body of a fully mature energy crop plantation acts like a 'green leaky dam' to hold water back both within and immediately upstream of the plantation and to slow the speed of water transmission across the floodplain. In most cases there will be a corresponding, but smaller, decrease in flood levels in an area immediately downstream of the plantation. The spatial extent of the hydraulic effect of a new plantation (whether fully or partially covering the floodplain width) or distributed plantations was found to be generally less than 300m upstream or downstream of the plantation edge.

The impacts caused by Miscanthus and SRC Willow plantations (typically grown in 1ha-3ha blocks) are broadly similar. However, flooding up to about 1m depth is likely to be more affected by Miscanthus than by SRC Willow primarily due to the different resistance to flow characteristics up to this depth. The difference between the two crops is expected to disappear with deeper flooding.

Plantation headlands and rides (vehicular access ways either around or within plantations) provide faster preferential (short circuit) flow pathways than the main vegetative block. Varying of the headland and ride width (from 5 to 10m) did not significantly change the flood dynamics. Varying the ride/headland orientation relative to the main river channel orientation did not significantly change the flood dynamics.

It should be acknowledged that other physical characteristics of the floodplain also influence the mechanisms of flood conveyance, attenuation and storage. These include the floodplain microtopography, embankments, open water features, bridges, and field boundaries (hedges and walls). The nature and scope of this short term project restricted the hydraulic analysis to just include the vegetative cover and the topography components.

It is very important to note that the modelling scenarios used to inform these guidelines do not represent exhaustive combinations of floodplain characteristics and the plantation configurations. Also, the commentary on the magnitude of change is based entirely on the results from the case study floodplains used in the modelling study. Therefore, any application of the findings to other floodplain situations and/or plantation configurations must be undertaken with caution.

Summary results matrix- magnitude of impact on flood dynamics

Plantation Configuration On Floodplain	Flood depth (max)			Flood velocity (max)				In-channel flood flow (max)		
	upstream plantation	within plantation	downstream plantation	upstream plantation	within plantation	within ride	downstream plantation	upstream plantation	within plantation	downstream plantation
Complete (100%) coverage	n/a	+/++	n/a	n/a	--	+	n/a	n/a	+	n/a
Distributed blocks (<30% coverage)	+	+/++	+/0	-	--	+	-	-/0	+	+/0
Central block (full floodplain width)	++	++	-	-	--	+	0	-/0	++	+/0
Central block (part floodplain width)	+	+	-	0	--	0	0	-/0	+	+/0

Table notes

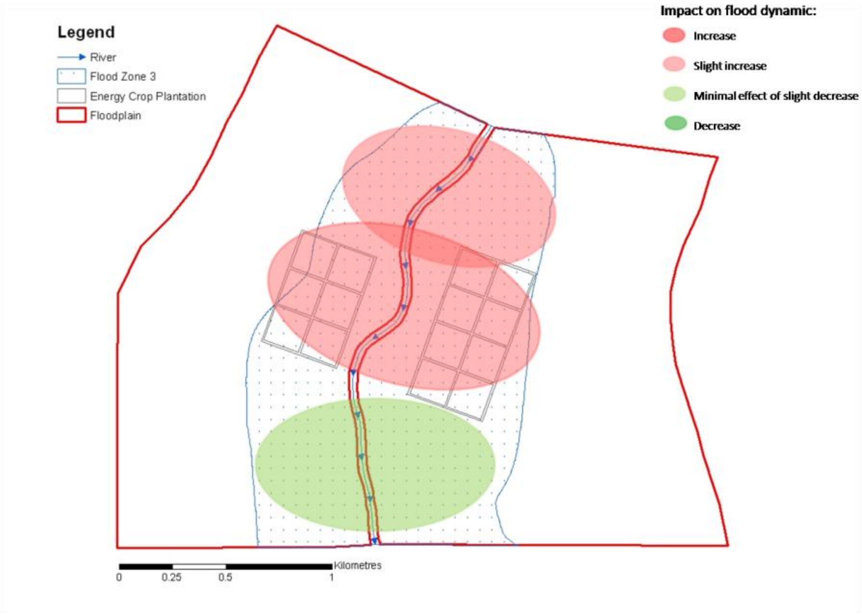
Symbol	Definition	Max flood depth change	Max velocity change	In-channel peak flow change
++	Increase	>20cm increase	>40% change	>10% increase
+	Slight increase	5-20cm increase	10%-40% increase	2%-10% increase
0	Minimal effect	±5cm increase/decrease	±10% increase/decrease	±2% increase/decrease
-	Slight decrease	5-20cm decrease	10%-40% decrease	2%-10% decrease
--	Decrease	>20cm decrease	>40% decrease	>10% decrease
n/a	Not applicable (not within model domain)	n/a	n/a	n/a

In line with the long term objectives of the Catchment Flood Management Plans (CFMPs) these energy crop plantations could potentially have an important role to play in helping to manage smaller-scale flooding problems where the high cost of constructing hard defences cannot be justified. These plantations could also make a valuable contribution to tackling the increased risk of flooding associated with climate change. The potential magnitude and spatial extent of the hydraulic impacts generated by a particular plantation configuration, especially with respect to third party land and property, will determine the nature and scope of the flood risk assessment that is required.

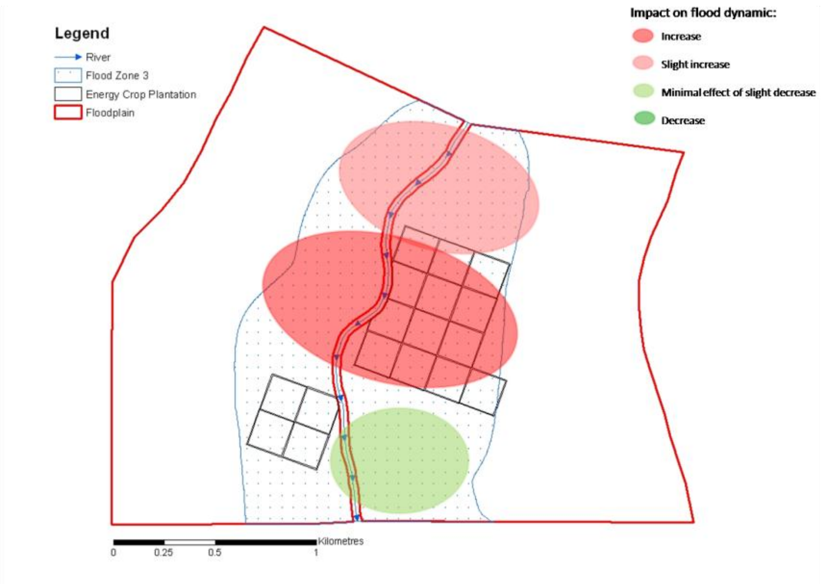
Plantation configurations with a limited impact on floodplain flows

Well distributed and dispersed plantations (comprising a number of 1ha-3ha blocks) with less than 30% total floodplain coverage, set away from the main channel, and therefore not significantly blocking the full floodplain width (i.e. not greatly impeding the flow of water across the floodplain) will only produce localised effects on the flood dynamics. A plantation that effectively blocks up to one side of a floodplain will only produce relatively localised effects on the plantation side of the floodplain. However, in this situation (and very much dependant on the particular floodplain physical characteristics, especially with respect to topography) more water could potentially be forced onto the opposite side of the floodplain and therefore onto an area under a different land ownership.

Impact of plantations configured as central blocks (part floodplain width)



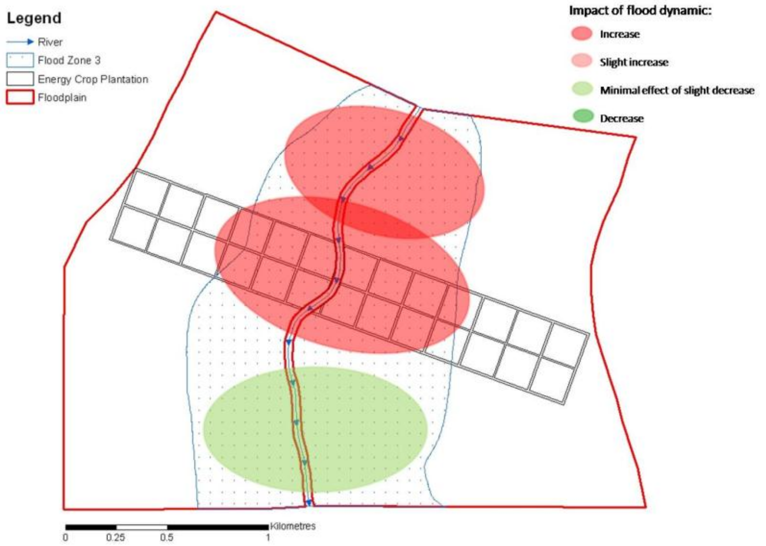
Impact of plantations configured in distributed blocks



Plantation configurations with significant impacts on floodplain flows

Full floodplain coverage of an energy crop plantation generated the highest overall impacts on the flood dynamics (e.g. flood depth, velocity of flow, main channel flow hydrographs). However, the presence of such a complete block of this type on the floodplain is not a realistic scenario. A single plantation block that extends fully across both sides of the floodplain will also generate a greater impact on the upstream area, both to the retardation effect of the vegetation on the floodplain flows and the resulting rise in water levels. The greater the plantation coverage the more water is forced to move in the vicinity of the main channel (and at greater flow velocity and flow rate).

Impact of plantations configured as central block (full floodplain width)



Planning Applications for new energy crop plantations

Any new plantation proposal should be supported by a proportionate assessment of flood risk, which should be sufficient to demonstrate that there is no significant detriment to third parties, or to the ability of the Environment Agency or other responsible bodies to maintain river channels and other flood risk management infrastructure. As detailed in the existing Environment Agency guidelines for this type of development any new plantation proposal will be considered against a set of screening criteria to determine whether or not a detailed Flood Risk Assessment (FRA) is needed. In many situations an FRA will not be needed. However, if deemed necessary, a detailed FRA should comprise the following:

- Location Plan
- Level survey to Ordnance Datum
- Plan showing structures affecting local hydraulics
- Assessment of impact of planting areas on water levels
- Assessment of impact displaced water on other property
- Assessment of potential blockage of structures
- Cross-sections of the existing and proposed site
- Assessment of impact on fluvial morphology
- Clear and comprehensive summary

In certain situations it might be appropriate to undertake some more detailed hydraulic modelling in order to fully explore a number of the specific assessment items listed above. Also, on some floodplains there may also be important environmental (e.g. Sites of Special Scientific Interest), heritage (e.g. Scheduled Ancient Monuments) and landscape receptors that would require careful consideration.

To date, most research regarding roughness coefficients (such as the Manning's n coefficient) in hydraulic models has mainly focused on the physical characteristics of the river channel (bed and banks), with relatively little having been undertaken on the extremely variable characteristics of vegetated floodplains. The published roughness values for floodplain vegetation have generally concentrated on more conventional land cover types, namely common arable crops, grassland, and woodland. Wet woodlands or wet meadows have recently been seen as potentially providing a useful flood attenuation function in suitable locations on floodplains, together with other ecosystem services, and these have been subject to a small number of hydraulic modelling studies. There is very little published information to date specifically on the roughness characteristics of energy crops such as Miscanthus or SRC Willow and how these vary during the growth and harvesting cycles of these crops.

The modelling approach that was developed for this study included a fully linked 1D - 2D ISIS - TUFLOW model, which is a widely used industry standard flood inundation software package. A review of published roughness Manning's n coefficients, together with consultation with researchers in this area, ascertained that the following table of Manning's n values were appropriate for the hydraulic modelling of energy crops.

Vegetation type	**Manning's n coefficient**	**Comments**
Miscanthus	0.2	Manning's n applied for all depths of inundation
SRC Willow	0.1 – 0.34	Manning's n varies linearly with depth of inundation as follows: n=0.1 flooded depth < 0.5m n=0.34 flooded depth 2.0m
Headlands/Rides	0.04	Manning's n typically used for managed grass for all depths of inundation
Baseline (used for comparison)	0.06	Manning's n typically used for arable crop (winter wheat) for all depths of inundation