Department of Geography and Environmental Science

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A high-density wireless underground sensor network (WUSN) to quantify hydro-ecological interactions for a UK floodplain; project background and initial results

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Background

We present the rationale and initial results of the **FUSE** (**F**loodplain **U**nderground **SE**nsors) project. FUSE aims to advance our knowledge on the interaction between the **hydrological regime (and related thermal and nutrient regime)** and the functioning of plant communities in **floodplain meadows**, at a variety of scales; a better understanding of these vulnerable ecosystems will allow **improved environmental management, under changing climatic conditions**. This aim will be achieved via sophisticated **high-resolution model-data fusion**, involving: a wireless underground sensor network (**WUSN**); high-resolution hierarchical **observational data** (**in-situ and remote sensing**); and state-of-the-art **modelling**.

FUSE Field site

Yarnton Mead (Fig. 1) is one of the **ancient hay meadows** of the **Oxford Meadows** Special Area of Conservation. River Thames **floodplain deposits** of alluvium (Fig. 2) underlie the Meads, ranging from 0.3 to 3 m in thickness, on top of sands and gravels. Groundwater levels beneath the Meads are high, with **groundwater flooding** occurring in low-lying areas during most winters. Occasionally, **overland flooding** also occurs.

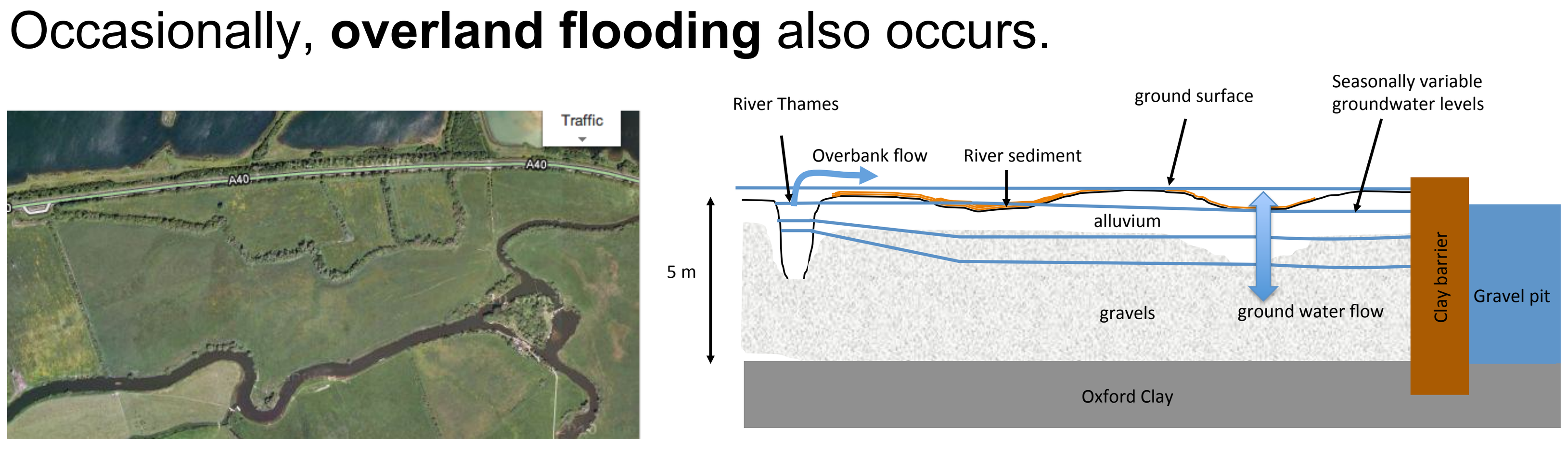

Fig. 1. FUSE study site. Left, an areal photograph of Yarnton Mead, right a pictorial cross-section of the site.

We sample **the floristic and phenological variation (Fig. 3)** of the plant communities**, the canopy exchange, groundwater levels, soil physical** (moisture/temperature, via WUSN at ~ 50 locations; to be established) and **meteorological** variables.

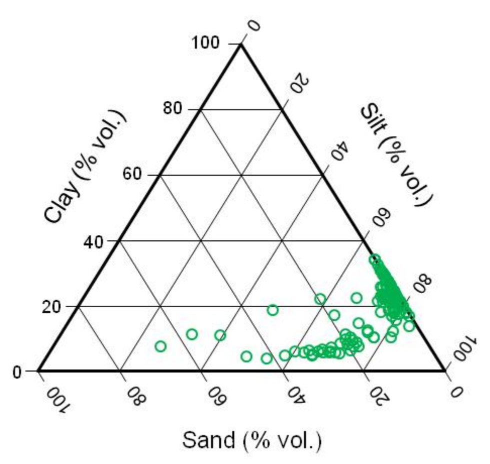

Fig. 2. Alluvium textural composition

Fig. 3. Yarnton Mead vegetation

WUSN challenges at Yarnton Mead (YM)

- Yarnton Meadow is **used by humans** for recreation and hay-making, **grazed** by animals, and is protected as a **SSSI**. Therefore, unsightly above-ground hardware and tripping hazard has to be minimised → solution: **W**ireless **U**nderground **S**ensor **N**etwork
- WUSN needs to stay in place for ~ 2 years so **battery life** is of paramount importance; low-powered WUSNs are relatively unexplored
- **Soil** (especially near or at **saturation**) causes extreme attenuation of the underground signal; at YM there is a large spatio-temporal variation in **soil moisture content** due to groundwater and overbank **flooding**, which causes **antenna detuning**
- **Soil texture** varies horizontally and vertically (clay loam on top of sand, Fig. 2); sand allows for better signal propagation than clay
- **Underground (UG) signal propagation** is highly complex: we have to take into account heterogeneous soil, reflections at surface, surface-wave propagation and diffraction
- Spatio-temporal variation in **root- and vegetation layer thickness** and Leaf Area Index will affect **above-ground (AG)** signal propagation. The **water content** contained on (after rainfall) and within the canopy will also play a role.

Preliminary Results

Existing research (see Table 1) claims low-powered WUSNs are infeasible with 433 MHz Mica2 motes.

Table : Maximum internode distance for PER <30%

	-3 dBm	0 dBm	+5 dBm	+10 dBm
UG2UG	55 cm	55 cm	85 cm	95 cm
UG2AG	200 cm	200 cm	250 cm	300 cm
AG2UG	15 cm	25 cm	55 cm	85 cm

Table 1. Taken from: "Development of a Testbed for Wireless Underground Sensor Networks", by A. Silva and M.C. Vuran, EURASIP Journal on Wireless Communications and Networking; special issue on "Simulators and Experimental Testbeds Design and Development for Wireless Networks", 620307, 2010.

However, preliminary field experiments show that our WUSN is able to achieve **~100% success at 4m** spacing at **433MHz** (see Fig. 4) and up to **30m** at lower frequencies (results not shown).

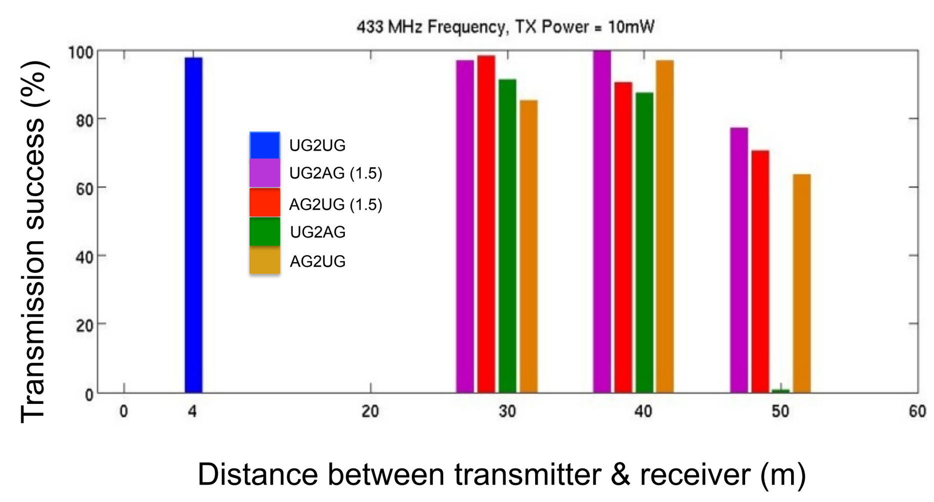

Fig. 4. Influence of distance between transmitter and receiver upon packet transmission. Experiment conducted at IC Prince's Garden (London, UK). Soil texture was highly variable, largely due to a wide variation in gravel content (20-70 % weight fines, 28-74 % weight sand, and 0-49 % weight gravel); (1.5) indicates AG node elevated to 1.5 m height.

Anticipated contributions of FUSE project

- Analysis of **radio communication** through soil with high soil moisture contents, w.r.t. soil composition, vegetation cover etc.
- **Optimal antenna configuration** for UG2UG, AG2UG,UG2AG communication
- Heterogeneous UG2UG **multi-hop network topology** & **multi-gateway scheduling/synchronisation**
- Intelligent **interface between motes** and soil-moisture, water-level, and temperature **sensors**.
- **Cognitive radio protocols** to adapt to spatial & temporal variations in soil conditions
- **Energy conservation strategies** to extend WUSN lifetime (>2 yrs) - soil disturbance is unwelcome.

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- Other research partners on **FUSE** are: British Geological Survey, Wallingford, UK; Open University, Milton Keynes, UK; Rothamsted Research, UK; Southampton University, UK; ITC: University of Twente, Enschede, NL; Environment Agency, UK; Natural England, UK.
- http://www.fuseproject.org.uk/