

Gandhi Marine National Park. During the survey we also detected potential threats to dugong populations like marine litter, fishing boats and high-speed vessels used for SCUBA diving and game fishing.

In this study we conducted a survey using light-weight unmanned aerial vehicles (UAVs) to detect marine mega-fauna and study dugongs in India. Our observations show that light-weight UAVs can be effectively used to detect a wide range of marine species, understand species distribution patterns, estimate their populations and quantify threats. Given the lack of a reliable population estimate for dugongs in the country, we strongly recommend UAV surveys to be implemented at all dugong distribution sites to aid their conservation. Further, UAV surveys should be adopted as a tool by State Forest Departments to monitor marine fauna of conservation concern and for tackling illegal activities in the Marine Protected Areas.

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Soil matric potential-based irrigation using tensiometer for conserving irrigation water

Intensively cultivated rice–wheat cropping sequence has several sustainability issues^{1,2}. GRACE-NASA, the US gravity mapping satellite, has detected a 30 cm yr⁻¹ drop in subsurface water in North India over a 440,000 km² area, resulting in a 4 cm decline of under groundwater³. In Punjab, India, the water table is declining at an alarming rate because of increase in the area under rice to 60% (in 2015) compared to 6% in the 1960s. In addition, each year in Punjab, more than 13 lakh ha-m of extra water worth US\$ 39 million is provided for irrigation purposes. Resource conservation

technologies (RCTs), viz. direct seeded rice⁴, bed planting, mechanical transplanting⁵, laser levelling⁶, soil matric potential-based irrigation using tensiometers, etc. could reduce water footprint in rice^{4–8}. Tensiometer is the only instrument in the hands of the farmers which guides them when and how much to irrigate⁹. Interpretation of tensiometer readings is easy and farmer-friendly, which helps the farmers decide on the timing of water application based on crop need and soil textural class which also cover the effects of other conditions like rainfall, etc. It is the first gadget of its kind which

helps in deciding how much stress could be given to a crop without affecting land productivity¹⁰. Different tensiometers are available for recording soil matric potential at different depths. Further, these readings are not affected by temperature, and variations, thus the instrument could be effectively used in different parts of world experiencing different temperatures without any difficulty.

The matric potential is one of the components of the total soil water potential that also includes gravitational (position with respect to a reference elevation plane), osmotic (salts in soil solution),

gas pressure or pneumatic (from entrapped air) and overburden components. The sum of matric and gravitational potentials is the main driving force for water movement in soils and other soil-like permeable media¹¹.

Generally, in agricultural experiments for wheat crop, after a pre-sowing irrigation the first irrigation is done at 28 days after sowing (DAS), which is common to all the plots. At soil matric potential reading of -35 kPa at 35 cm depth, the fields were irrigated to meet the plant requirements (Figure 1). The last irrigation to wheat crop was done 10–15 days before crop harvest. In rice crop, the puddled plots were irrigated to ensure ponded water conditions up to 15 days after transplanting (DAT). Reirrigation applied when the tensiometer potential readings reached -15 kPa at 15–20 cm soil depth¹, since more stressed conditions could result in yield loss.

The different components of a tensiometer are reservoir, cork and acrylic transparent tubes which consist of internal and external tubes. Water is filled in the internal tube which is directly linked with a porous ceramic cup, while the external tube provides strength. Various coloured strips, viz. green, yellow and red coinciding with different levels of soil matric potentials, based on the water level inside the inner tube and the soil are provided at the top of the outer tube. The cork does not change its shape with temperature fluctuations, thus keeping the system air-tight even during the hottest months of the year. Both the tubes and the ceramic cup are filled with distilled water overnight prior to installation in the paddy fields. Farmers are preparing for irrigation after having a look at the coloured strip of tensiometer. The tensiometer determines how forcefully water is detained in the soil particles and not how much water permeates into the soil. Light textured sandy soil cannot offer as much water to the plant as offered by heavy textured clay loam soils.

Research has revealed that tensiometer-based irrigation scheduling saves considerable amounts of irrigation water without having any adverse effect on land productivity. Figure 2 depicts that during 2006, considerable amount of water was saved with a mean value of 30.2% and with almost similar crop yields. However, during 2007 to 2010, the water footprints of rice reduced to

26.1%, 22.9%, 18.7% and 16.25% (ref. 6). Kukul *et al.*¹ reported reduced water footprints under tensiometer-based irrigation compared to flood irrigation without any loss to crop yield, which further improved irrigation water productivity to 75.8% (Figure 3). Also, irrigation water productivity increased by about 55% with tensiometer-based irrigation over

intermittent irrigation (two days gap) in rice.

However, during the intervening period, soil matric tension (SMT) readings revealed that permanent zero-tilled plots evaporated at higher rates than the conventionally tilled plots. This might be because of removed crop residues in the former tilled plots which resulted in



Figure 1. Tensiometer used in agricultural research at Punjab Agricultural University, Ludhiana, India.

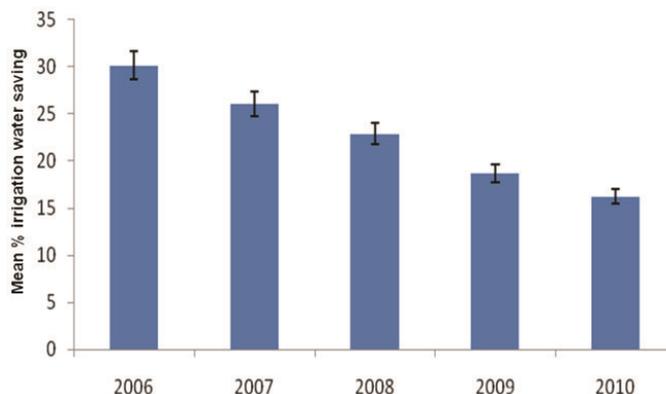


Figure 2. Irrigation water saving with tensiometer in Kapurthala, Punjab, India.

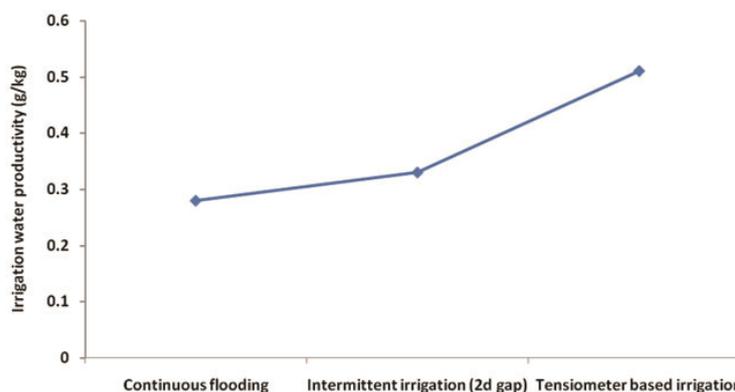


Figure 3. Irrigation water productivity of puddle transplanted rice.

higher soil temperature, vapour pressure gradients, higher upflow of water vapour and finally higher moisture loss. However, continuity of soil pores is broken, which reduces vapour outflows and finally evaporation during the intervening periods in the conventionally tilled plots which reduces down the profile. Tension values increased as the interval between wheat harvesting and rice seedlings transplanting progressed. At 0.1 m soil depth, tension readings in conventionally tilled wheat followed by zero tilled direct-seeded rice (CTWDSR-ZT) were 36% higher than the readings after conventionally tilled wheat followed by puddled direct-seeded rice (CTW-DSR-P). Soil matric potential varied with the same tune at 0.2 and 0.3 m at all sites of puddled direct-seeded rice (DSR-P), conventionally tilled direct-seeded rice plots (DSRCT), and zero tilled direct-seeded rice (DSR-ZT) plots⁷. At 0.3 m depth, in DSR-P plots, SMT values were 12% and 11% higher under conventional tillage in wheat (CT-W) block and zero tillage in wheat (ZT-W) sites respectively, than the associated sites. At the ZTW sites, SMT readings increased at a significantly higher rate (24%) than CT-W sites throughout the profile, indicating higher soil moisture in the latter plots⁴. The influence of different crop establishment techniques on soil matric potential was analysed using tensiometers at 10, 45, 60, and 90 cm soil depth during the rabi of 2013–14 in wheat⁷.

Tensiometers help in saving significant amounts of irrigation water (which could be used in other relevant sectors) (Figure 4)¹² and the energy/power to extract it from underground (Figure 5). In 2012 water saving was maximum of 16% in Tarn Taran followed by 14% in Ludhiana and Amritsar districts, while in 2013 it was 19% in Moga and Tarn Taran districts of Punjab. Power saving was a maximum of 127 kWh/acre in Moga district followed by 113 kWh/acre in Ludhiana in 2012, while in 2013 it was a maximum of 100 and 67 kWh/acre in Moga and Amritsar districts respectively¹². Tensiometers helped reduce water utilization in rice by 14–15% (Figure 5). Commonly, irrigation application based on tensiometer helps in reducing the rice water footprint; thereby, the saved water could be diverted to other potential sectors like industrialization, urbanization, etc. This water saving further is linked with saving in power/

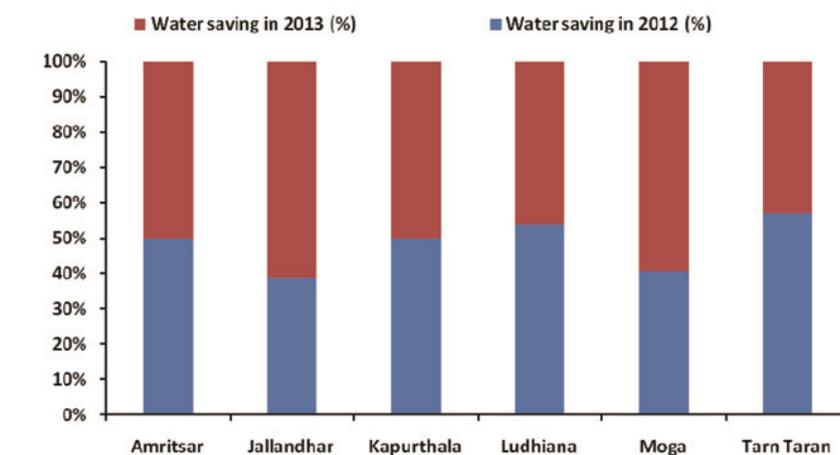


Figure 4. Residual effects of tensiometer on water saving in different districts of Punjab.

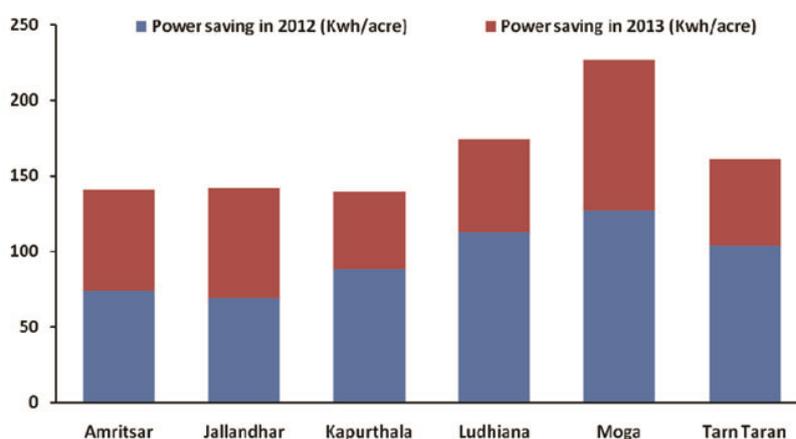


Figure 5. Residual effects of tensiometer on power saving in different districts of Punjab.

electricity used to draw this extra water deep from the ground.

Intensively cultivated rice–wheat cropping sequence along with faulty agricultural practices have led to a hydrological imbalance in Punjab. The increasing population has further complicated the situation, requiring increased food production which in an ever increasing population is a challenge for the agricultural scientists. Water resources are continuously exploited in unsustainable manner without considering future prospects in mind. Tensiometer-based irrigation water and power saving provide a new hope for sustainable and climate smart agriculture. Technologies which could sustainably reduce water footprint are gaining popularity among paddy farmers. Agricultural ultimate water users, viz. farmers might achieve the same yields with 70% of the irrigation water used before. Things must be ana-

lysed in integrated approaches, wherein different individuals, who contribute to reducing water footprints, must get aside and research their previous failures and plan future strategies to save irrigation water inputs. However, tensiometer results differed, which could be due to changes in soil textural class, cultivar selected, sowing date, rainfall incidence and amount. Thus, there is a need to carry out further research on this aspect in texturally divergent soils under different agro-climatic conditions.

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