Cosmic-Ray Neutron Sensing for Measuring Soil Water Content at Area Wide Scale: Case Study at IAEA and Future Collaboration

*Ammar Wahbi[1], Trenton Franz[2], Hami Said Ahmed[3], Lee Kheng Heng[3], Peter Strauss[4], Hisashi Tsujimoto[1], Haruyuki Fujimaki[1]

1. Arid Land Research Center, Tottori Univeristy, Tottori, Japan, 2. School of Natural Resources, University of Nebraska-Lincoln, Nebraska, USA, 3. Soil and Water Management & Crop Nutrition Subprogramme, Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, International Atomic Energy Agency, Vienna, Austria, 4. Institute for Land and Water Management Research, Federal Agency for Water Management Austria, 3252 Petzenkirchen, Austria

General circulation models predict that annual rainfall rates in many countries will decline by the end of the century. Coupled with population growth, there will be stiff competition for water resources. It is therefore important that new and advanced irrigation technology be developed to help mitigate this challenge. Currently, 40% of global food production comes from irrigated areas that account for only 20% of the cultivated land. Regrettably, water use efficiency in many irrigated systems around the globe is less than 50%, as most of the applied water does not go towards plant transpiration. Hence, there is an urgent need for improvement in the efficiency with which irrigation water is applied to secure sufficient water for both humans and the ecosystem. One critical gap is the disconnection between current techniques for measuring soil moisture at plot-scale with water (and fertilizer) decisions often for larger areas. This difference in scale creates uncertainty and thus inefficiency in water resource management. To overcome this pressing challenge, the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, the University of Nebraska (USA) and the Federal Agency of Water Management (Austria) have helped advance the nuclear technique (Cosmic-Ray Neutron Sensor, CRNS) that measures soil moisture over large area scale, compared with point sensor, by counting naturally occurring low-energy neutrons in the air above the selected area. The neutrons are created by incoming cosmic rays, providing an average soil moisture measurement over a ~10 ha of circle area and a depth of ~30 cm. The CRNS technique is a nuclear technique that does not need a radioactive source, with low power consumption, allowing for either stationary or mobile measurements.

There are 3 types of the devices, stationary which stay in place and can provide reading every one hour, backpack which can move in areas difficult to access and read few minutes, while rovering which is carried by a vehicle at low speeds and measures every minute. The last two are used for two- or three-dimensional heterogeneity mapping to measure the soil water content within the footprint.

The data of CRNS are freely available with about 70 devices in USA, and over 200 in independent networks around the world (mainly in developed countries), with additional data sets from developing countries in recent years.

In this study, we highlighting the research investigated and carried out by the Joint FAO/IAEA Division of the International Atomic Energy Agency using CRNS.

The research conducted at several studied sites in Austria. The Petzenkirchen study which is within the Austrian Institute for Land and Water Management Research, with heterogeneity cropping, employing stationary CRNS, has been established in Dec.2013 and it provides major dataset for this study, although we also used the backpack for short times. It represents a small watershed in a hilly area of northern foot

slopes of the Alps. Also, we used the backpack in Grabenegg (which is 5 km away from Petzenkirchen, and has a homogeneity cropping pattern). Apart from that short-term measurement campaigns were carried out using backpack CRNS in alluvial plain east of Neusiedler See Lake and in mountainous areas of Rauris Municipality, at different heights, in the central part of Austrian Alps. This study describes the results and interpretation of about 7 years of soil moisture data set (2013-2020).

In this study, we will present the calibration and validation of CRNS and illustrate the future research and constraints using this technology. We will also highlight future collaboration possibilities with institutions in Japan.

Keywords: Cosmic-ray neutron sensor, Soil water content, Dry land, Irrigation, IAEA, Austria

