Chapter 5

Water Cycle Process Research: Experiments and Observations

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Additional information is available at the end of the chapter

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Abstract

The evaluation of methods and instrumentation for measuring water cycle parameters and for monitoring the status of hydrological process will assist governmental personnel, researchers, and water resources practitioners in determining strategies for field and laboratory measurements. This chapter aims to specify the instruments and techniques developed during the long-term monitoring phase of field experimental stations and the establishment phase of indoor experimental laboratory in the Key Laboratory of Water Cycle and Related Land Surface Processes, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences. The two field experimental stations, Dongtaigou and Chongling, have been initiated to observe and quantify the water cycle process for more than 10 years, which has formed a complete set of observing and experimental methods in watershed. The experimental laboratory is a new integrated water cycle experiment platform, based on the new technology integrated control, measurement, sensors, and information processing. It includes artificial rainfall system, experimental sink of runoff and erosion, river simulation system, and transformation dynamical processes experimental device among precipitation, vegetation water, surface water, soil water, and groundwater. The continued instrumentation development and advanced experimental strategies will serve as a first port of call for professionals studying the behavior of water footprint.

Keywords: field station, experimental laboratory, instruments and techniques, water cycle, experiments and observations

1. Introduction

An understanding of water cycle processes is essential for assessing water resources as well as the changes to the resources caused by changes in the land use or climate. Experimentation and observation are central activities within the water cycle process research. The range of measuring and monitoring instrumentation and techniques for defining water cycle process variables is immense. Hence, this chapter is not intended to be a comprehensive overview of such instrumentation and techniques, but to present the specific instruments and techniques developed during the long-term monitoring phase of field experimental stations and the establishment phase of indoor experimental laboratory in the Key Laboratory of Water Cycle and Related Land Surface Processes (KLWCRLSP), Institute of Geographic Sciences and Natural Resources Research (IGSNRR), Chinese Academy of Sciences (CAS).

To investigate the dynamic changes in land surface water cycle and the related geographic processes, the KLWCRLSP established two field experimental stations and one indoor experimental laboratory. One station is Dongtaigou Field Station and the other is Chongling Field Station. The experimental laboratory is experimental hall of water and soil process. To clearly demonstrate the water cycle principle, we present a chapter introducing experimental approaches. This chapter is valuable for studying mechanism of water cycle processes *in situ* as well as in the laboratory. The goal of this chapter is to illustrate the development and application of innovative experimental techniques broadly across the areas of subsurface and surface hydrology and hydrometeorology.

2. Field experimental stations

2.1. Dongtaigou Field Experimental Station

Dongtaigou Field Experimental Station is one of the field stations of IGSNRR, CAS, in Dongtaigou catchment (**Figure 1**). It was established in 2003 and designed for the long-term observation of water cycle processes impacted by soil and water conservation projects.

Dongtaigou catchment is a part of the Baihe watershed in the northern part of Yanshan Mountain in Northern China (40° 45′N, 116° 37′E). A detailed water cycle experiment has been initiated in a 0.64 km^2 research catchment [1].

The slopes in the catchment are steep, with an average of 30° and altitude of 290–530 m. The south-north oriented catchment is in the temperate zone and a semi-humid monsoon climate, with average annual temperature of 9–9.5°C and precipitation of 511 mm. The precipitation occurs mainly in June–September with the type of storms which take up 81.2% of the total amount of the year. The bedrock of the region is mainly andesite, covered with meager cinnamonic soil. Constrained by the natural conditions, the catchment has a single and simple vegetation with the coverage of 70%. It is covered with perennial shrubs and herbs such as twigs of the chaste tree, axillaries, and apricot and a small amount of other economic trees such as hawthorn and pear.

Detailed observations of surface and subsurface water dynamics have been made at the catchment. The instruments hydrometrically observing the dynamics of soil water, groundwater, and stream flow response to rainfall and evaporation are described as follows:

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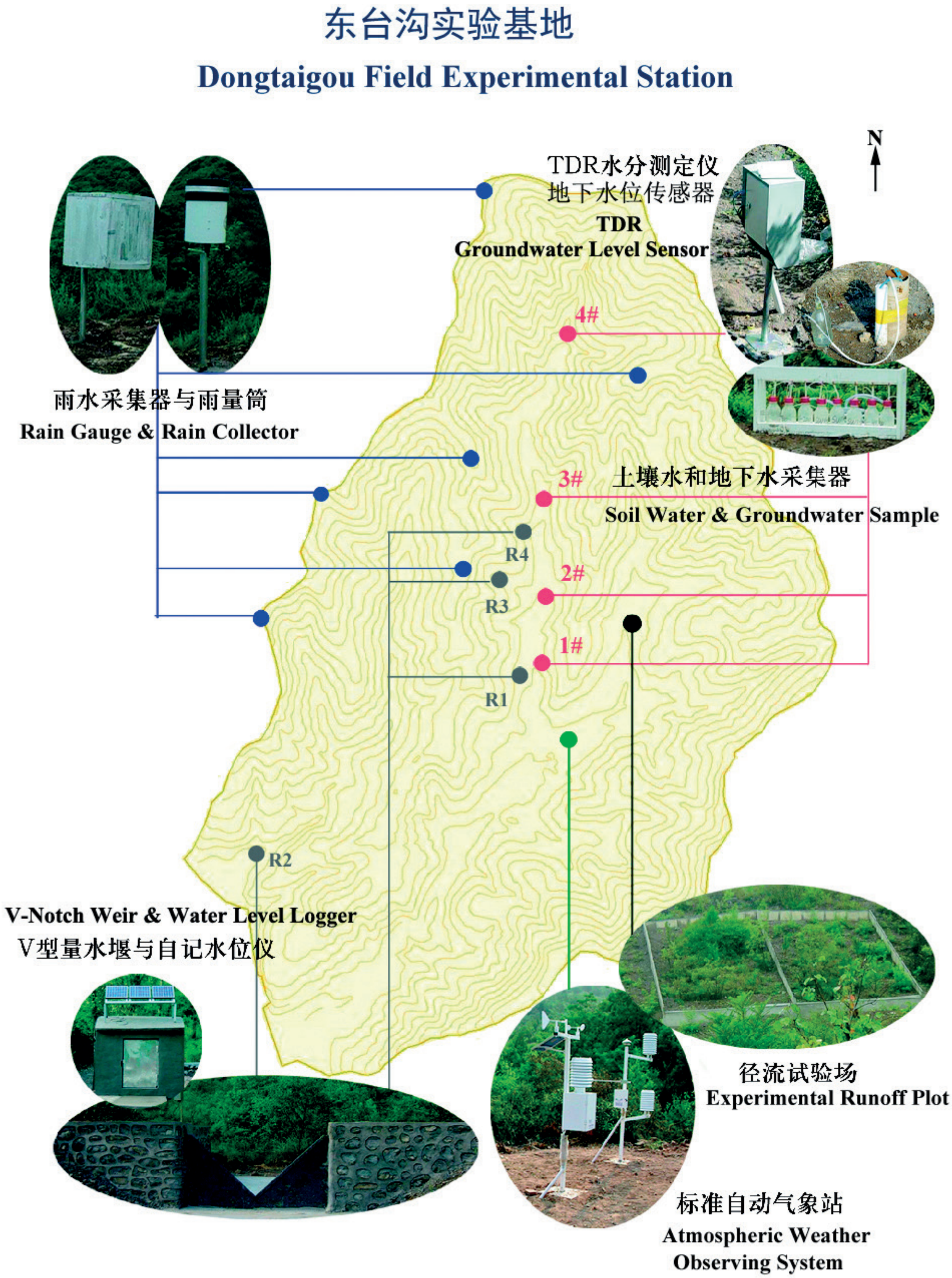

Figure 1. Layout of the Dongtaigou experiment catchment, showing measurement instrumentation and structures.

2.1.1. Meteorological observation

The Atmospheric Weather Observing System is located at the center of meteorological field at outlet of catchment (**Figure 1**). It is made by monitor sensor company (www.monitorsensors.com) to make observations of atmospheric conditions [2]. The measurements taken include air temperature, humidity, wind speed, wind direction, barometric pressure, solar radiation, net radiation, precipitation, evaporation, photoactive radiation, soil temperature, soil moisture, and soil heat flux. The data are automatically recorded every 5 min except the rain gauge (every 1 min) and evaporation sensor (every 30 min). The evaporation is measured as the depth of water (in mm) from the Class A Pan. For the accurate measurement of soil profiles, soil moisture sensors are installed at 10, 15, 30, and 40 cm depths, temperature sensors at 0, 10, 20, and 40 cm depths, and soil heat flux sensors at 15 cm depth.

2.1.2. Precipitation observation

There are six HOBO Logging Rain Gauges (Onset Computer Corporation) monitoring the precipitation of catchment (**Figure 1**). The rain gauge is a self-contained device that includes a high-quality tipping-bucket with an integrated data logger. The tipping-bucket mechanism is designed such that one tip of the bucket occurs for each 0.2 mm of rainfall. Each bucket tip is detected when a magnet attached to the tipping bucket actuates a magnetic switch as the bucket tips, thus effecting a momentary switch closure for each tip. The switch is connected to a HOBO Event Data Logger, which records the time of each tip.

In the catchment, precipitation is sampled for hydrogen and oxygen stable isotopes and main ions analysis. A rain collector consisting of a polyethylene bottle and funnel is placed outside and a ping pong ball is positioned at the funnel mouth to prevent evaporation during rainfall. After each rainfall event, rainwater is collected and immediately transferred to a bottle and sealed and stored [3].

2.1.3. Soil water moisture and groundwater level observation

Along the channel region, four observing pots are arranged namely 1#, 2#, 3#, and 4#. The DataTaker DT50 (Thermo Fisher Scientific Australia Pty Ltd, http://www.datataker.com/) is employed to sample the Time-domain reflectometer (TDR) probes and groundwater level sensor (DS30, SEBA Hydrometrie GmbH & Co. KG). The frequencies of data collection are 10-min interval in the flood season and 30-min interval in non-flood period. A total of four TDR probes are installed horizontally at depths of 20, 40, 70, and 100 cm to continuously monitor soil moisture throughout the 110 cm soil profile. The groundwater level sensor is fixed in a depth in which all possible water levels are within the measuring range. The pressure sensor always measures the water above the sensor. To measure the distance between the ground and the water table or the height of water table above sea level, the parameters of the recording device must be changed correspondingly.

Soil water samples are collected after rainfall. Soil water is sampled at the depth same as that of sensor, using a suction lysimeter designed by IGSNRR, which was composed of a Teflon pipe and porous ceramic tube. A vacuum pump of about −0.8 MPa is applied to the suction lysimeter for 12 h of equilibrium to collect soil water [4]. The ground water sample is collected directly from pump discharge.

2.1.4. Surface water runoff monitor

Two small catchments are carefully selected as the contrastive study site. One is named Donggou in which 22 stonemasonry dams were constructed (R1), and the other is Xigou with conservation of the natural environment (R2). There are also two little similar branches in Donggou (R3 and R4). Four V-notch weirs mounted into the concrete are built at the outlet (**Figure 1**). Odyssey Capacitance Water Level Logger (Dataflow Systems PTY Ltd, New Zealand) is used to monitor the surface water level. The logger automatically records the water level at a 1-min interval. The surface water is sampled from the stream when flooding. The sampling container is completely filled and then capped and properly stored.

2.1.5. Experimental runoff plot

Two experimental runoff plots (5 × 10 m) have been established on mid-slopes as indicated in **Figure 2**. The two plots are covered with shrubs mainly consisting of Vitex negundo var. heterophylla, wild jujube, wild grass, and two cypresses [5]. The plot borders are made of concrete. The edges of the runoff plots are about 50 cm above the soil surface to prevent input from splashes entering the plot from the surrounding areas and are sufficiently embedded into the bedrock so that the water insides and outsides will not exchange. In order to examine water horizontal processes on the overland, in the shallow soil, and the soil bedrock interface, three layers of water movement are monitored at the down slope end of the plot. A pipe is positioned at very layers, and a V-Notch (Triangular) Weir tank (410 mm long, 210 mm wide, and 305 mm deep) was installed to collect the runoff which would then be piped into a collecting cylinder [6]. The weirs from top to bottom are 210 mm high with 30, 20, and 20° V-notch thin-plate, respectively. The collecting cylinder is made of a metal sheet and covered with a sheet metal to prevent direct entry of rainfall. Runoff volume is calculated by measuring the head of water over the V-notch crest. The total volume of runoff is measured by volumetric method to calibrate the runoff calculated from the wire [7].

Meanwhile, a few measurements are also made to observe rainfall, soil water content, and soil water potential dynamics. An automatic recording tipping bucket rain gauge is installed some 3 m from side plot. In assessing the relationship between water content and capillary pressure head (tension), a comparison is made between the prevailing capillary pressure heads recorded by the automatic tension meters at the time of the TDR probe automatic measurements. The probes are installed at 10, 20, and 30 cm depths in two separate profiles up and down of plot. Campbell Scientific CR10X data loggers (Campbell Scientific Inc., USA) are employed to sample the TDR probes (20-min step), tension meter sensors (20-min step), and water level sensors of wires (1-min step).

2.2. Chongling Field Experimental Station

Chongling Field Experimental Station was constructed in 2004 by Key Laboratory of Water Cycle and Related Land Surface Processes (KLWCRLSP), cooperated with Baoding Soil and

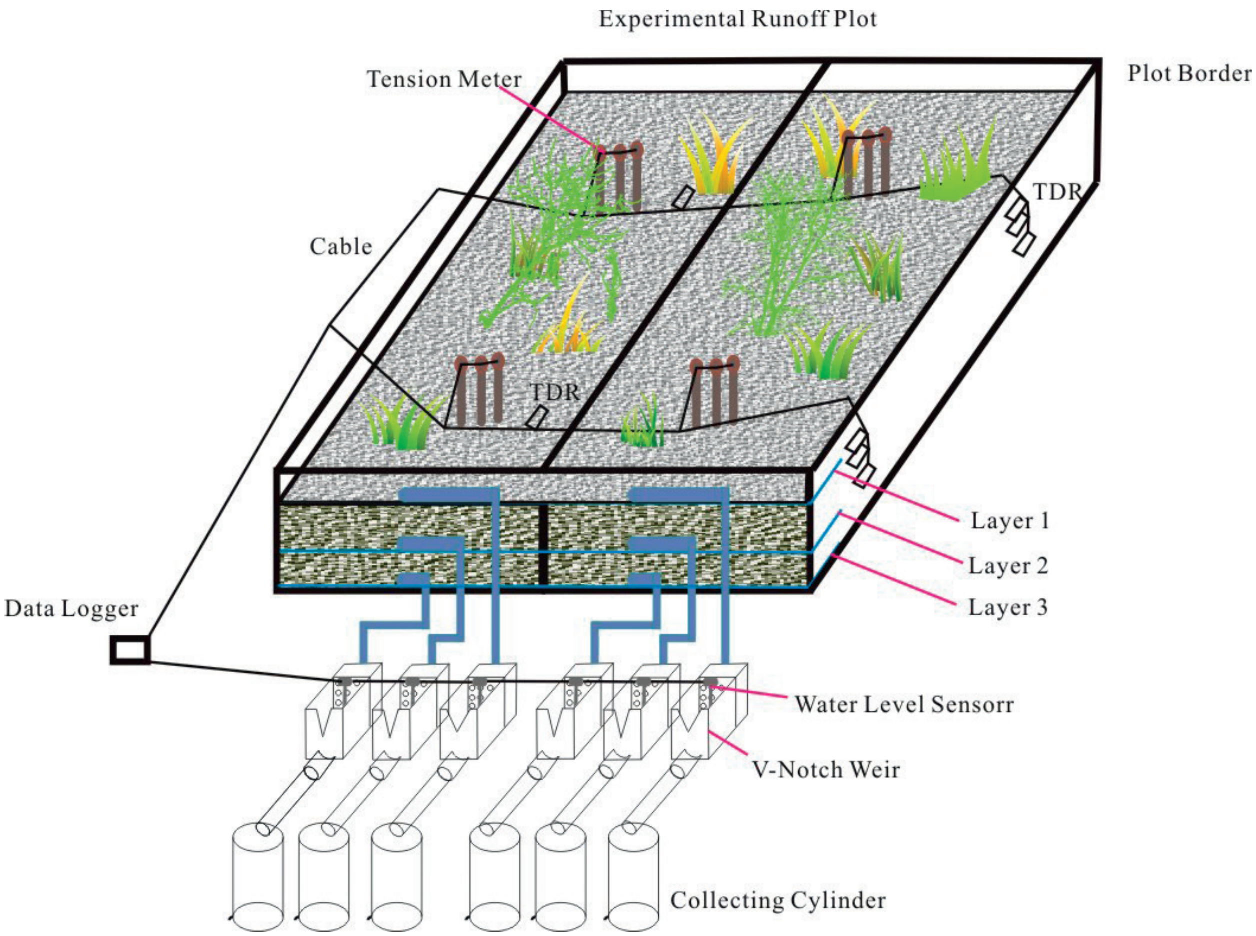

Figure 2. Schematic representation of two experimental runoff plots.

Water Conservation Station. It is also one of the field stations of IGSNRR, CAS and has been developed into a prime research location involving many institutions.

It is located in Chongling catchment in Yixian County, Hebei province of China (115° 21′E, 39° 23′N). Chongling catchment is in the north of Taihang mountainous region, which is a tributary of north Yishui River. It covers a total area of approximately 6 km^2, with a length of 4.4 km and a width of 1.5 km at an altitude of approximately 70–300 m above the sea level. The research catchment was chosen for studying on hydrological process affected by typical vegetation in North China.

The area has a temperate climate with average annual air temperature of 11.6°C, and the maximum and minimum temperature is observed in July and January with extreme values of 40 and −23.4°C. There are dry season (from September to May) and rainy season (from June to August). The annual precipitation ranges from 217.0 to 1004.3, on an average of 641.2 mm. The mean annual evaporation is 1906 mm by E601B Evaporator. The soil type in the catchment is predominantly sandy loam soil and loess, which is mainly cumulated in the valley, with depth of 1–2 m. The vegetation coverage in this area is diversified, including woody plants (Acacia, Arborvitae, Poplar, Pine), shrubs (*Vitex negundovar*, *Ziziphus jujuba* Mill. var. spinosa), and herbage (*Carex humilis*, *Carex lanceolata*, *Bothriochloa ischaemum*) [8].

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The catchment drains in a southeasterly direction and the contributing hillslopes are each divided into five gully channels from east to west of the watershed, that is, Yangshugou, Wanmulingou, Yanghuaigou, Langweibagou, and Huyaogou. There are also two little gully channels (Chenglingou and Langyaogou) in the southeast of the watershed.

A summary of the instruments observing the precipitation, surface water, soil water, groundwater, and so on is presented in **Figure 3**.

2.2.1. Comprehensive meteorological observation

A meteorological field (25 × 2 5 m) has been made at Chongling catchment since 2004, providing a continuous, very high-quality record as shown in **Figure 3**. The instruments include Vantage Pro2 Weather Station (Davis Instruments Corp., USA), E601B evaporation pan (China), Φ20 cm evaporation pan (China), eddy covariance (EC), and flux observation system.

The Vantage Pro2 station includes a console and a versatile integrated sensor suite. The console displays and records the station's weather data every 10 min, provides graph and alarm functions, and interfaces to a computer using the WeatherLink software. The sensor suite to the console is used to monitor wind speed and direction, temperature and humidity, wind chill, dew point, barometric pressure, ultraviolet radiation, heat index, temperature humidity sun wind (THSW) index, rain rate, and solar radiation.

Evaporation is determined by the water levels, which are monitored by automatic logger (E601B pan) and by manual measurement (Φ20 cm pan). For automatic measurement of the evaporation, use is made of an Odyssey Capacitance Water Level Logger (Dataflow Systems PTY Ltd, New Zealand). The sensor is supplied with Teflon-covered measuring element and the logger stores measurements at 1-min interval. Manual evaporation pan measurements are made by measuring the volume of water in the evaporation pan. Manual measurements are made twice a day, at 8:00 a.m. and 6:00 p.m., to see the difference between day evaporation and night evaporation.

There is an eddy covariance and flux observation system in the northeast corner of the field [9]. The measurements of eddy covariance (EC) are made from the tower at 20 m height, and the setup consists of three-dimensional sonic anemometer (CSAT3, Campbell Scientific, Inc., USA), an open-path CO_2/H_2O analyzer (Li-7500A, LI-COR, Inc., USA). The frequency of data acquisition is 10 Hz. In addition to the EC measurements, several meteorological variables, such as air temperature/relative humidity (HMP155A-L, Vaisala Oyj, Finland) and wind speed (010C-1, Met One Instruments, Inc. USA), are measured at about 2, 6, 12, and 20 m heights above the ground. Furthermore, incoming and outgoing short- and long-wave radiation (CNR4 Net Radiometer, Kipp & Zonen B.V., The Netherlands), photosynthetically active radiation (LI190SB, LI-COR, Inc., USA), and wind direction (020C-1, Met One Instruments, Inc., USA) are measured from the tower at 20 m height. To deal with water movement in soils, the soil profiles are selected to measure the soil water content (CS616, Campbell Scientific, Inc., USA), temperature (109-L, Campbell Scientific, Inc., USA) at 10, 20, 40, and 80 cm depths, and heat flux (HFP01, Hukseflux Thermal Sensors B.V., The

Figure 3. Layout of Chongling catchment showing the location of instruments.

Netherlands) at 5 cm depth. The data are automatically recorded in the CR3000 data logger (Campbell Scientific, Inc., USA) at a 30-min interval.

2.2.2. Precipitation observation

There are six rain gauges monitoring the precipitation of catchment (**Figure 3**). The rain gauge is the tipping bucket rain gauge type (SL3-1) made by Shanghai Meteorological Instrument Factory Co., Ltd. The two buckets in a tipping bucket rain gauge rest on a pivot so that when one bucket has received 0.1 mm of rain, it tips by gravity, empties the rainwater, and allows the other bucket to start collection. During the tip, an electrical switch is closed and triggers the HOBO Event Data Logger (Onset Computer Corporation, USA) to register each "tilt," thus giving a fairly continuous record of precipitation.

Six rain collectors are placed near the rain gauges to sample the rain water. After each rainfall event, rainwater is collected and immediately transferred to a bottle and then sealed and stored.

2.2.3. Soil water potential observation

Soil water potential has been monitored at four deferent sites consisting mainly of grassland, one under acacia and two under old arborvitae. Soil water potential is observed by automated tensiometer in the catchment [10]. Each site has one profile, and the depths of observation are 10, 20, 30, 40, 50, 70, and 100 cm. The data are automatically recorded at 2-min intervals and averaged every 30 min by data logger (CR800, Campbell Scientific, Inc., USA).

Suction lysimeters designed by IGSNRR are used to collect pore water from unsaturated soil at four sites. After installation below ground level, vacuum is applied to the porous ceramic tube through Teflon pipe from bottle. The negative air pressure created inside the tube draws pore water into the tube through the porous ceramic tub. The pore water is transported to the bottle through Teflon pipe. Suction lysimeters perform best in moist soil and below the water table and work as long as the soil water potential is in the 0/-800 mbar range.

2.2.4. Surface water observation

Runoff is monitored at Youlingou (R1) and Langyaogou (R2) by the V-notch weir and outlet of catchment (R3) by the compound weirs (**Figure 3**). The compound weirs (**Figure 4**) are composed of V-notch weir (up), Flat V weir (middle), and Parshall flume (down) [11]. The weirs are instrumented with Odyssey Capacitance Water Level Logger (Dataflow Systems PTY Ltd, New Zealand). Water level-discharge relationships can be applied and meet accuracy requirements for the weirs. The runoff can be calculated according to water level-discharge relationship.

2.2.5. Groundwater level observation

Existing wells are selected and used for long-term water level monitoring. It currently includes 10 active observation wells located across the catchment. The locations of the wells are shown in **Figure 3**. Six wells (G1–G6) are manually monitored in the dry season (from November to April) every 10 days and in wet season (from May to October) every 5 days. The rest four

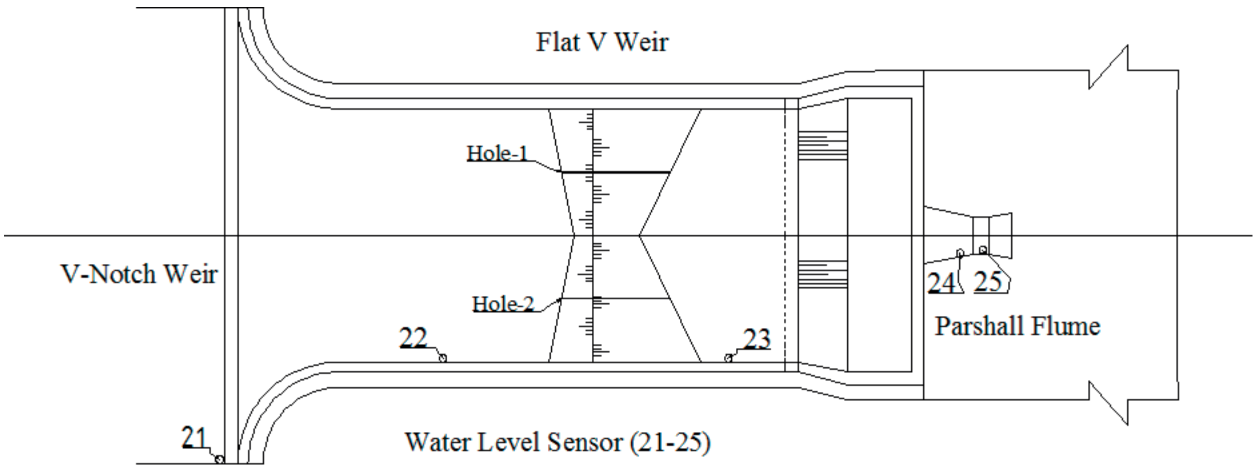

Figure 4. Schematic representation of the compound weirs.

wells are equipped with electronic data loggers that record water levels every 30 min. To date, a multi-parameter groundwater data logger (CTD-Diver, Eijkelkamp Soil & Water, The Netherlands) has been installed to monitor water level, conductivity, and temperature at G7. The KADEC-MIZU II groundwater monitoring data loggers (North One Co., LTD, Japan) are used to monitor the groundwater level at G8, G9, and G10. The wells are visited approximately every 1 month for field verification, and water samples are collected periodically to test groundwater chemistry. The ground water is directly pumped from the well and stored.

2.2.6. Throughfall and stemflow

To investigate the effect of different types of tree (Acacia, Arborvitae, and Pine) on the spatial variability of throughfall, throughfall collectors are partitioned into three zones as shown in **Figure 3** [12]. In each zone, one collector 1 m long, 1 m wide, and 20 cm high is made of a metal sheet and located at a fixed position. The collector is connected by polyethylene hose into the tipping-bucket flow gauge designed by IGSNRR (**Figure 3**). The gauge had been previously calibrated and recorded the by HOBO Event Data Logger (Onset Computer Corporation, USA).

The stemflow is measured simultaneously with throughfall. Three sets of stemflow collars are fitted to trees in each zone. The rubber collar is encircled at the trunk at an angle of approximately 45° to the horizontal at the level of the breast height (about 1.3 m above ground) and tightened closely with silicone sealant to avoid the leaching of water, as shown in **Figure 3**. The stemflow is diverted from the rubber collars to tipping bucket gauge similar to that used for gross rainfall via a PVC suction hose, 3 cm in diameter. The outputs from that are accumulated on HOBO Event Data Logger (Onset Computer Corporation, USA).

Gross rainfall amounts are measured in the neighboring open area, outside the forest, using the tipping bucket rain gauges (SL3-1, Shanghai Meteorological Instrument Factory Co., Ltd., China).

2.2.7. Experimental runoff plot

Two experimental runoff plots (5 × 15 m) have been set up on 15° slopes consisting mainly of pine and shrub, respectively. The plot borders 20 cm above the soil surface are made of

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concrete to prevent water loss and input from splash and are sealed with the bedrock to prevent the water exchange inside and outside of the plot (**Figure 5**). A pipe, connecting the collecting trough at two layers, is positioned at the downslope end of the plot to monitor the overland flow and base flow at soil-bedrock interface. From this pipe, the runoff flows into the collecting tanks (400 mm long, 200 mm wide, and 300 mm deep). The tanks are performed with a 210 mm high 30 and 20° V-notch thin-plate weir to measure the overland flow and base flow, respectively. The flow from collecting tank is piped into a collecting cylinder which is made of a metal sheet and covered with a sheet metal to prevent direct entry of rainfall. The water level sensor (L304S-3-B-F, Beijing Hua Yi Ao Feng Automation Equipment Co., Ltd, China) is installed in the tank. Runoff volume is calculated by weir equation. The total volume in collecting cylinder is measured by volumetric method to calibrate the runoff calculated from the wire.

The measurements, including soil water tension [10] and volumetric water content (EC5, Decagon Devices, Inc., USA), are also conducted at upper and lower sites in every plot. The probes are installed at 10, 20, 30, and 40 cm depths in two separate profiles. A Campbell Scientific CR1000 data logger is developed to record signals from soil water tension and volumetric water content sensors at a common 30-min time step and from water level sensor at

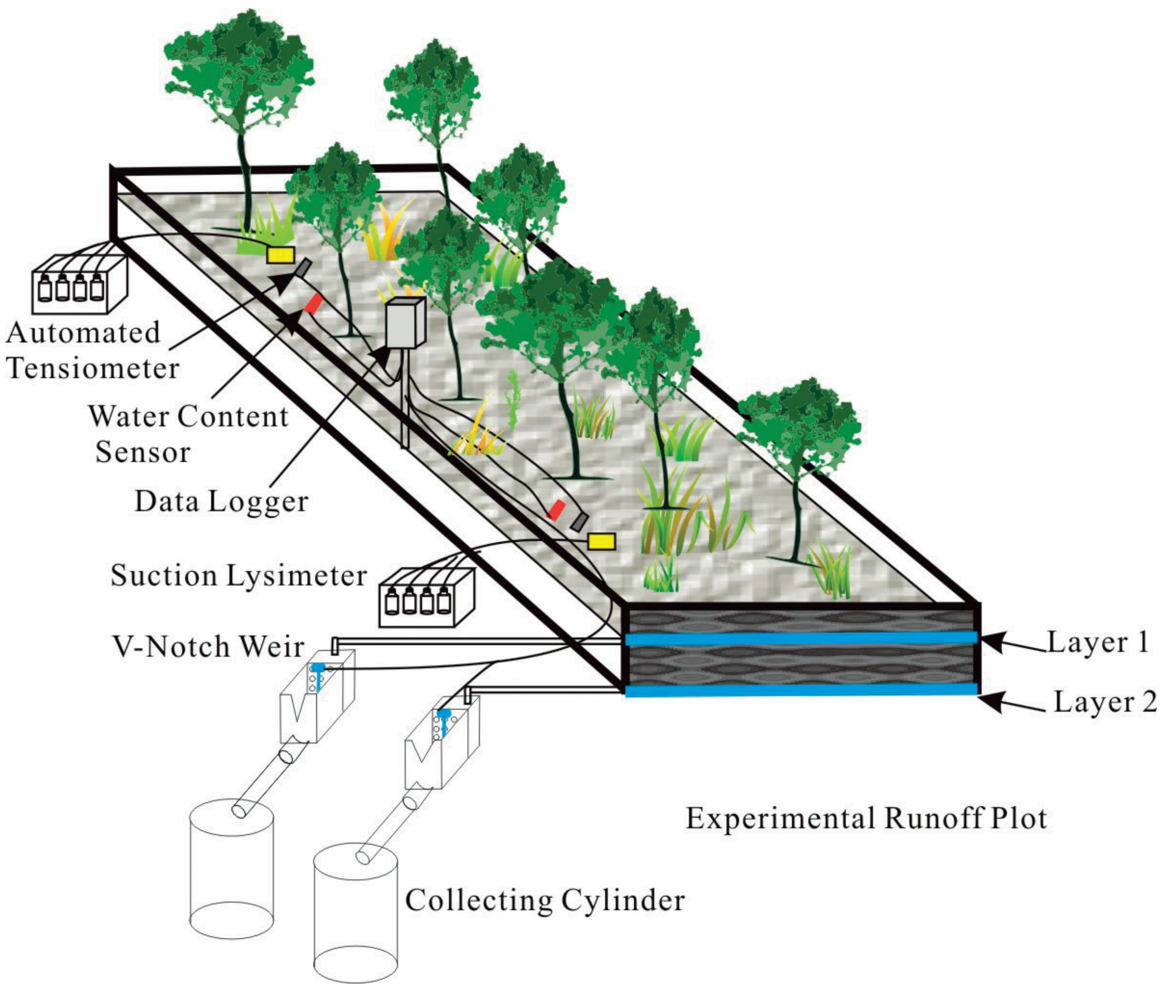

Figure 5. Layout of experimental runoff plot.

1-min time step. Suction lysimeters designed by IGSNRR are placed at the same depth of water potential sensors to collect pore water from unsaturated soil. The pore water is transported to the bottle through Teflon pipe.

2.2.8. Water runoff and erosion plot

In the catchment, a total of 13 water runoff and erosion plots were set up at both sides of the channel representing different type of vegetation. Eight plots (5 × 20 m) from P1 to P8 are located at southern hill slope of the channel. The plots are characterized by different vegetations, which are corns/wheat, bare, grasses, shrubs, paper mulberries, peanuts, peaches, apricots, *Phyllanthus urinarias*, and *Angelica keiskei*. Each runoff plot is located at a slope of 15°. The plot borders 50 cm above the soil surface are made of concrete and sufficiently embedded into the soil. At the downslope end of each plot is a trough, connected to a drum for storage of runoff. Two collecting tanks of the same size are used for each runoff plot.

In addition, a rainfall simulation system designed by IGSNRR is set up on the P1 and P2 plots. The system includes a submersible pump, electromagnetic flowmeters, sprinkler nozzles, and spray pipes (**Figure 6**). The sprinkler nozzle is installed at a height of 6.0 m so that the drops could reach a horizontal distance of at least 10 m to cover the whole 2 plots. Three rain gauges are positioned at every plot to monitor the simulated and natural rainfalls. A

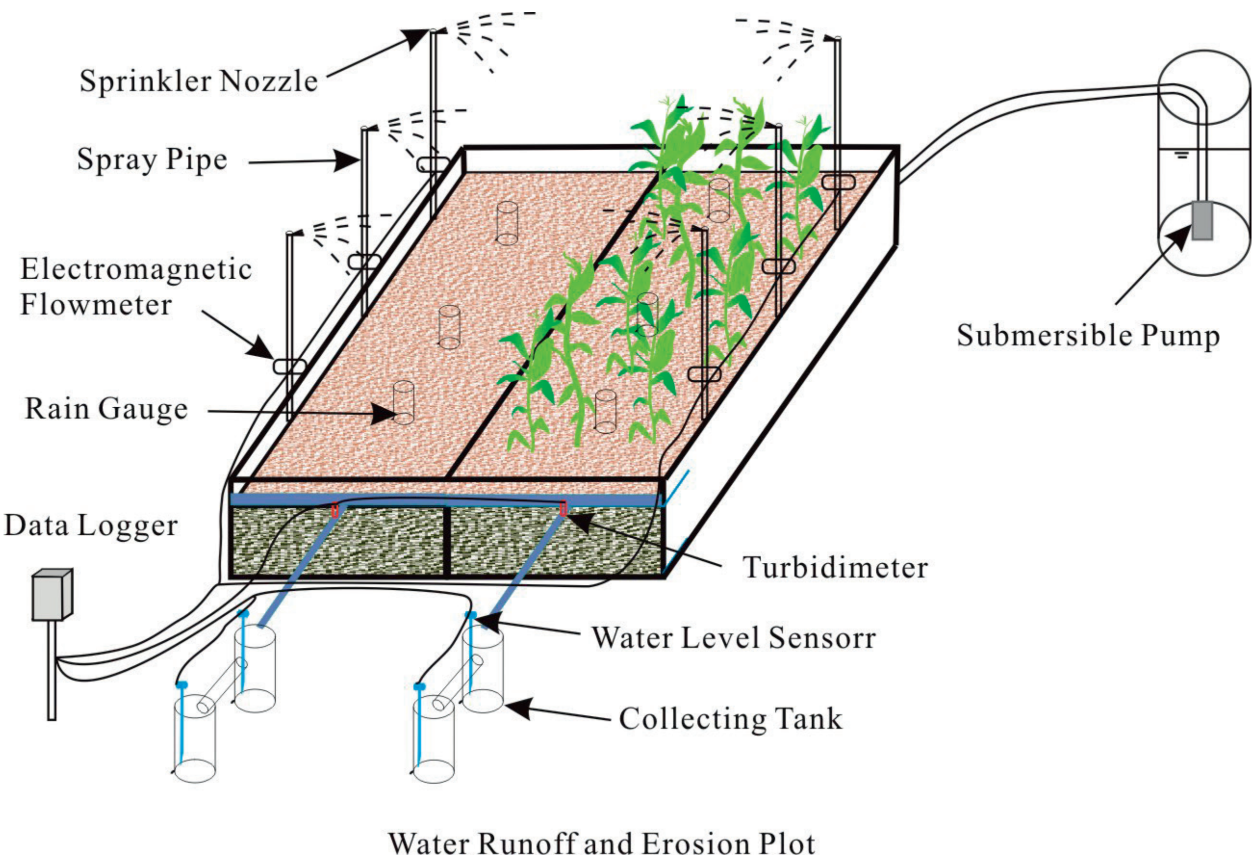

Figure 6. Schematic layout of water runoff and erosion plots.

turbidimeter (Ananlite NEP180, Mcvan Instruments PTY Ltd., Australia) and two water level sensors (L304S-3-B-F, Beijing Hua Yi Ao Feng Automation Equipment Co., Ltd, China) are installed in transferring pipe and collecting tanks, respectively, in plots 1 and 2. Volume of surface runoff was calculated by measuring the height of the water in the first and second collecting tanks. The sediment concentration is also calculated from the correlation and relationship between sediment concentration and turbidity. A Campbell Scientific CR1000 data logger (Campbell Scientific Inc., USA) is employed to automatically monitor the precipitation, pipe flow, runoff, and sediment concentration in plots 1 and 2 each min. Runoff collected from plots 3 to plot 8 is manually measured within a day after each runoff event. Meanwhile, a sediment sample is collected. Afterward, samples are dried and weighed to estimate their sediment concentration.

Five plots are located at northern hill slope of the channel. The size of the runoff plot is different due to the difficulty in finding the location with 20 m slope length. A collecting trough is positioned at the downslope end of the plot. Sediment and surface runoff from this collecting trough enter the first collecting tank, which splits overflow into five equal parts and passes one part, as a sample, into the second collecting tank. For each rainfall event, runoff volume and sediment loss from the plot are calculated.

3. Experimental laboratory

Experimental Hall of Water and Soil Process is located in the geographical museum of IGSNRR. It is 80 m long, 18 m wide, and 22 m high. It is a new integrated water cycle experiment platform, based on the new technology integrated control, measurement, sensors, information processing, developed from China's first artificial rainfall runoff laboratory, slope erosion laboratory, and fluvial geomorphology laboratory in the 1950s. It includes artificial rainfall system, experimental sink of runoff and erosion, river simulation system, and transformation dynamical processes experimental device among precipitation, vegetation water, surface water, soil water, and groundwater.

3.1. Artificial rainfall system

The artificial rainfall system finished in December 2015 is set up at the height of 18 m in the hall. It includes three rainfall zones: Z1, Z2, and Z3 (**Figure 7**). The total area is 370 m^2. The rainfall can be achieved in each separate zone or in all three zones at the same time. The system consists of variable speed pumps, stainless pipes, control center, laser rainfall monitor, and sets of solenoid valves and spraying nozzles (**Figure 7**). Every set of solenoid valves and spraying includes three valves and three nozzles which can be combined to produce 12–300 mm/h rain and mobile storm. A pressure-compensated flow control valve and a pressure gauge are located at the same altitude of the nozzle allowing a precise control of water pressure and consequently the constancy of rain kinetic energy. The artificial rainfall system is automatically regulated in the control center. The calibration tests showed that the uniformity of the rainfall intensities was greater than 85%.

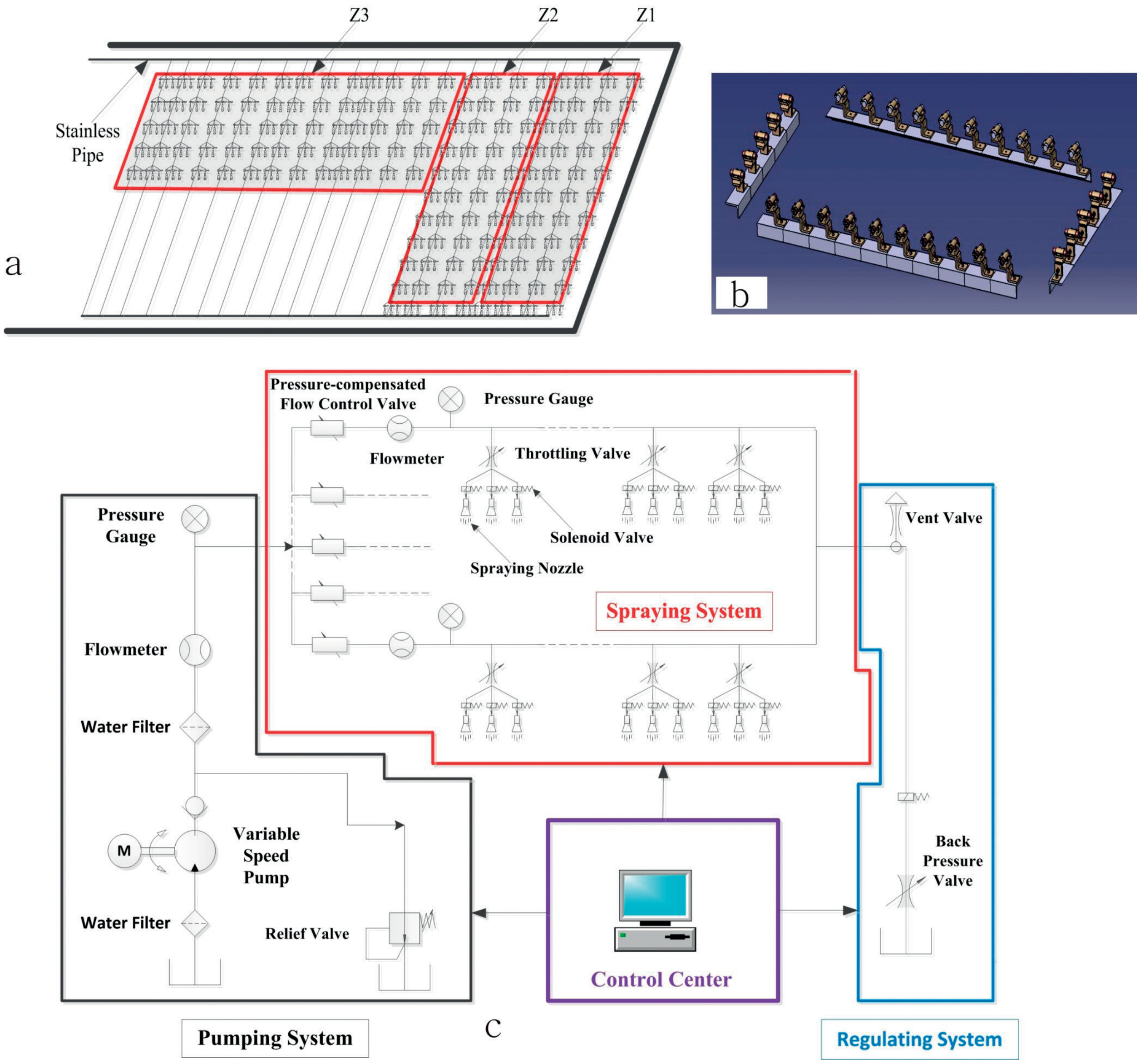

Figure 7. Schematic layout of artificial rainfall system: (a) three zones, (b) laser rainfall intensity monitor, and (c) four component sections.

Laser rainfall intensity monitor is installed at the mid-height of nozzles. It is composed of an array of laser transmitters and receivers (**Figure 7**). It achieves the rain non-touch measurement using orthogonally multiplexed laser beams according to the light attenuation law. The measurement error is less than 2%.

3.2. River simulation system

The river simulation system is 38 long, 6 m wide, and 1 m high (**Figure 8**). The borders are made of concrete and sealed with the ground to prevent water leaching from them. The crustal lifting simulation system is installed in the middle [13]. It is composed of 12 square steel blocks (2 × 2 m). Each block is supported by four stainless steel-threaded rods, which can be adjusted up and down. The 12 square blocks can be automatically motioned to form 82 types of crustal shape.

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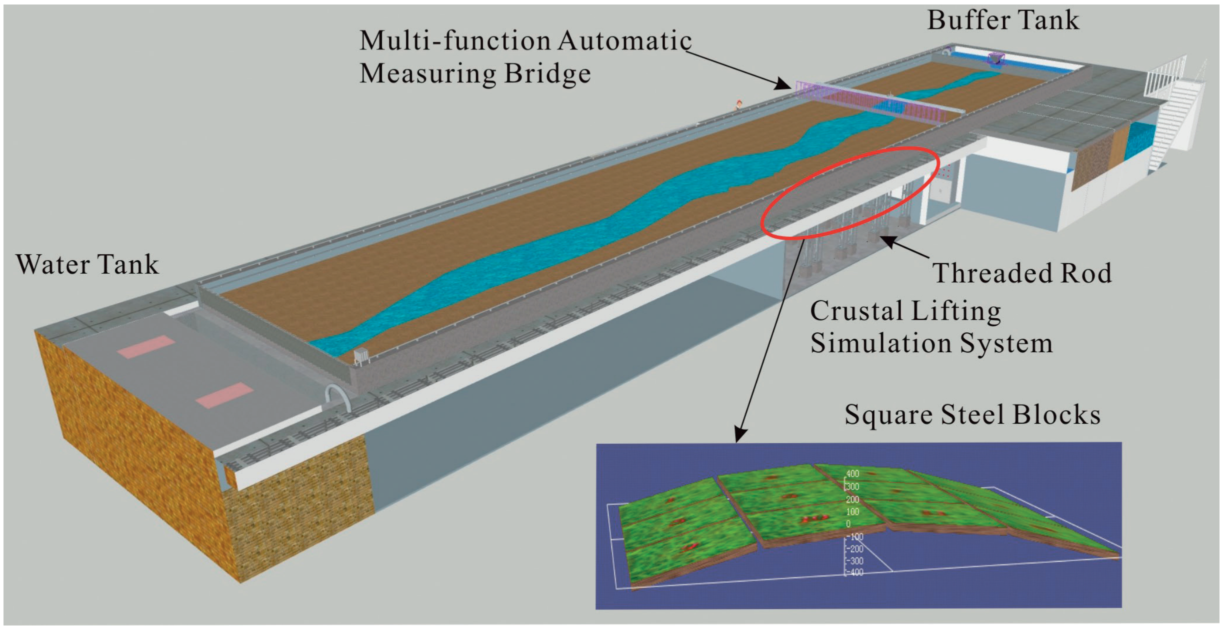

Figure 8. Schematic layout of the river simulation system (top) and one type of crustal shape (bottom).

The rate of motion is as slow as 30–70 mm/day. The multi-function automatic measuring bridge is placed above the system to move from the upstream to the downstream. It can automatically measure water flow, water depth, and cross-section of the modeled river. At the end, there is a big tank where the recycled water can be pumped to the upstream.

3.3. Experimental sink of runoff and erosion

It consists of two metal rectangular boxes, 10 m long, 3 m wide, and 0.8 m high, and each one is located under artificial rainfall zone 1 and zone 2 (**Figure 9**). The interval area, 1 m wide, is kept between the two boxes in order to easily assemble them into a bigger one. The slope of the experimental sink could be adjusted automatically from 0 to 35°. One 5 cm hole is cut into the downslope end of each plot. A short metal stub pipe is welded on to the hole to form an outlet. Two water flow monitors [14] are horizontally set up in front of the each box for the measurement of the runoff. The box outlet and flow monitor are fitted together with a flexible PVC pipe. The monitor should have lids to prevent direct rainfall from entering them. For simulated rainfalls, runoff volume measurements and sediment sample collection are performed every 5 s and 5 min, respectively.

3.4. Transformation dynamical processes experimental device among precipitation, vegetation water, surface water, soil water, and groundwater

The transformation dynamical processes experimental device among precipitation, vegetation water, surface water, soil water, and groundwater (TDPEDPVSSG) finished in July 2014 is a complex equipment to study the water process among the five different types of water (**Figure 10**). It is hermetically sealed in the house (7 m long, 5 m wide, and 7.5 m high) and consists of two sections joined together, the up section and the down section.

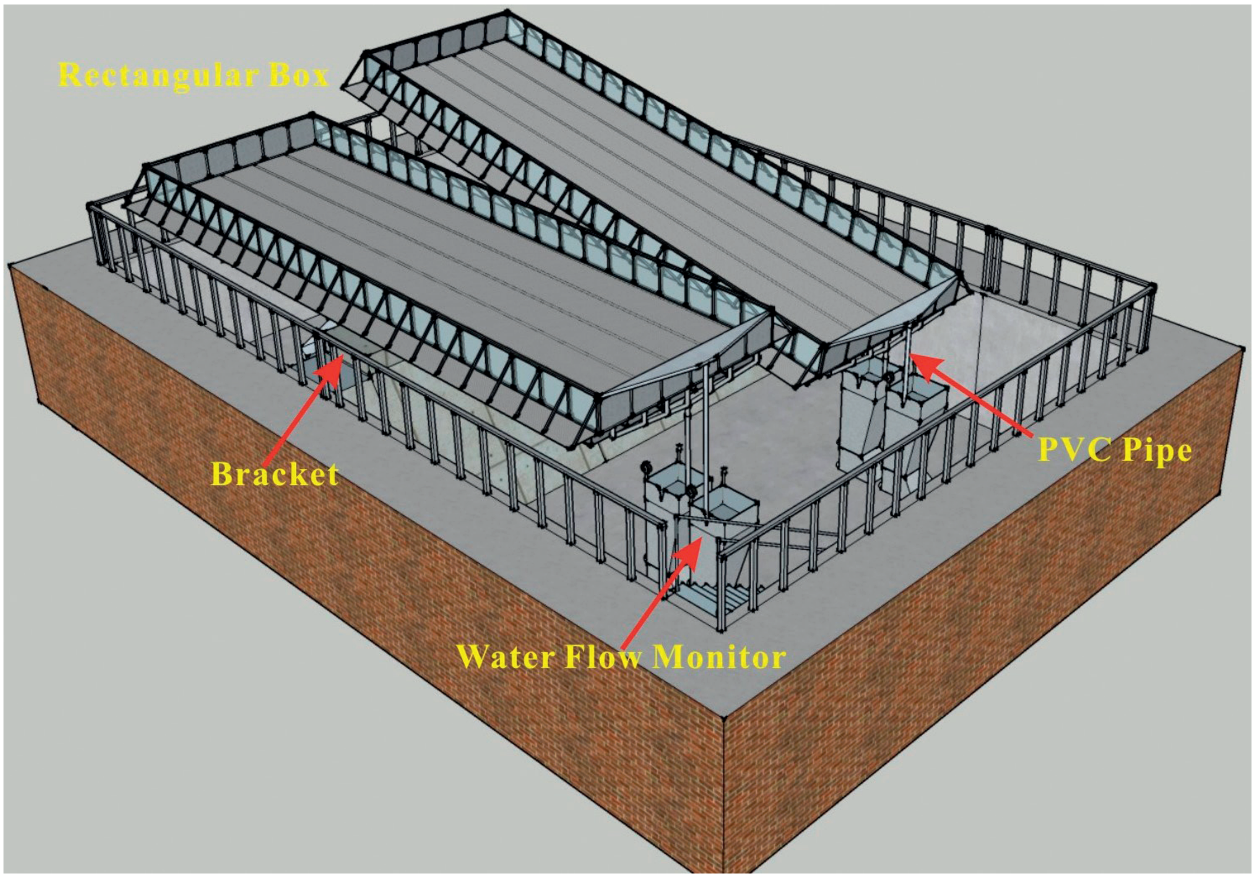

Figure 9. Schematic layout of experimental sink of runoff and erosion.

The down section has two weighable lysimeters. Each lysimeter has a rectangle stainless steel tank with a surface area of 6 m^2 (3 m long, 2 m wide) and a depth of 3 m. It is designed to have enough depth to accommodate the rooting depth of most plants and control the groundwater level. A drainage discharge and water supply system at the bottom is designed to facilitate the fluctuation of groundwater level. The gap between the concrete wall and the stainless container is less than 2 cm to avoid alteration of the energy balance of the system. This gap has been covered with a flexible and impermeable rubber film in the surface. Each lysimeter tank rests on a base frame that transmits the weight through a lever system with a counterweight to an electronic load cell. The lever arm reduces the majority of the total mass of tank and soil to a small fraction of some kilograms that are measured by load cell. It measures those soil mass with an accuracy of 60 g which corresponds to a precipitation or water column of 0.01 mm. The output signal of the sensor is transmitted to a computer located in the control room. The frequency of data collection is 30-min interval.

In the northern lysimeter, the silt loam is homogeneously placed. However, in the southern lysimeter, three horizons of soil (silt loam and silty sandy loam) are placed, and each horizon depth is 1 m. The type of soil structure is prevalent in this region of North China. Fourteen sets of soil moisture, temperature, and electrical conductivity sensor (5TE, Decagon Devices,

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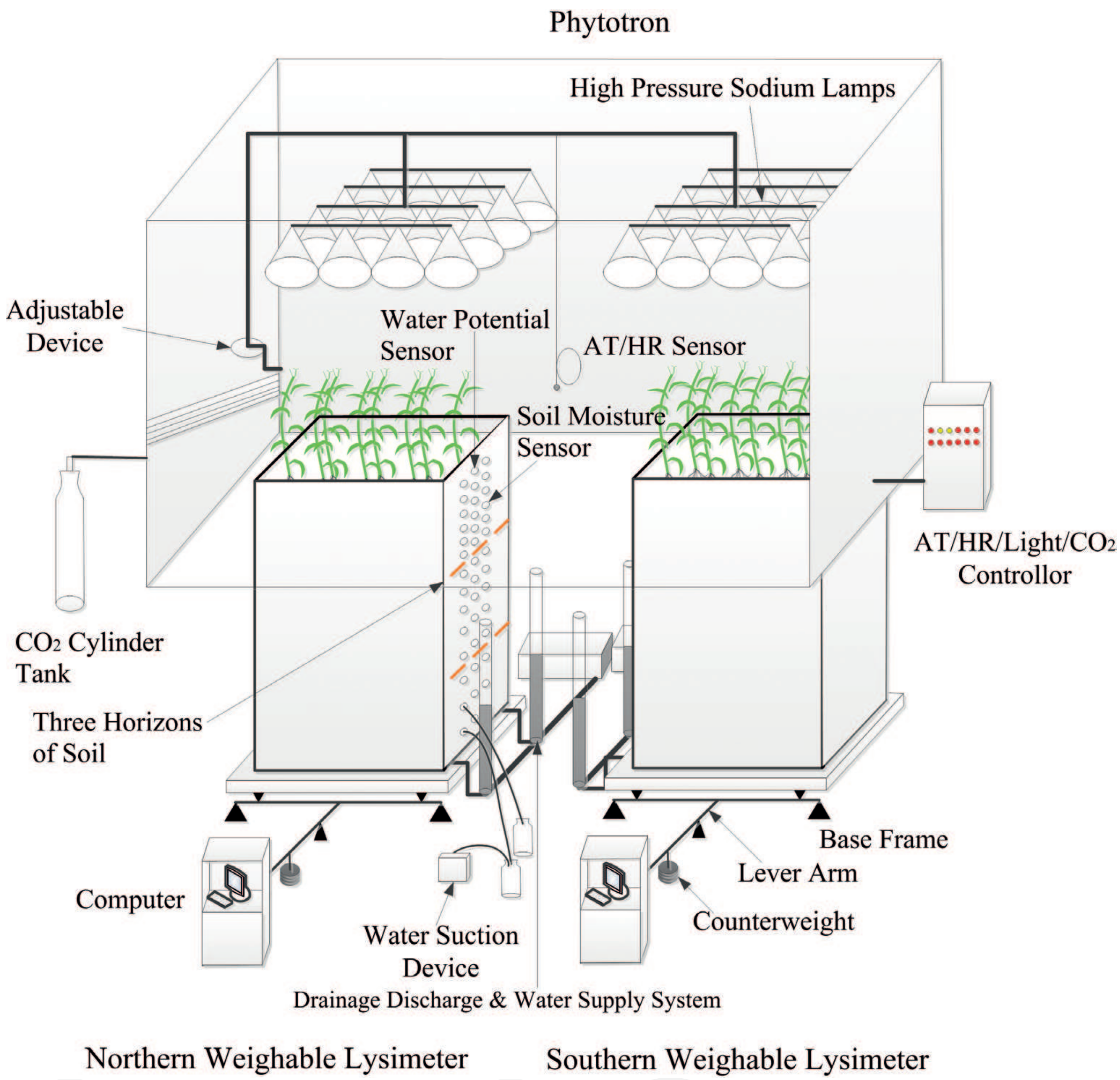

Figure 10. Schematic layout of the transformation dynamical processes experimental device among precipitation, vegetation water, surface water, soil water, and groundwater.

Inc., USA), dielectric water potential (MPS-2, Decagon Devices, Inc., USA), and suction lysimeter designed by IGSNRR are installed in side of the tank at the depths of 20, 43, 53, 63, 73, 83, 92.5, 110.5, 130.5, 150.5, 180.5, 210.5, 240.5, and 275.5 cm.

The up section is a phytotron where the temperature, humidity, light, and CO_2 can be automatically controlled. The temperature and humidity are generally controlled by air conditioner and humidifier. The light (0–30,000 LUX) is produced by 12 high-pressure sodium lamps above the lysimeter, which can be adjusted up and down manually. CO_2 is emitted from the steel CO_2 cylinder tank. The precision of controlling temperature, humidity, and CO_2 are ±1°C, ±5%, and ±100 ppm, respectively.

4. Conclusions

The instruments and techniques developed during the long-term monitoring phase of field experimental stations and the establishment phase of indoor experimental laboratory have been specifically described. The methods in the filed observations will enhance the quantitative research about the hydrology process. The new integrated water cycle experimental hall can be used to characterize the water movement among precipitation, vegetation water, surface water, soil water, and groundwater. These characterizations will improve the parameterization in numerical models. In addition, the continued instrumentation development and various techniques are recommended. It is particularly important to develop measurement and predictive techniques for *in situ* or indoor hydrological characteristics in the many instances.

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