

SYSTEMS AND METHODS FOR PLANT-LOCALIZED ATMOSPHERIC WATER HARVESTING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This Application claims the benefit of U.S. Provisional Application No. 63/581,950, filed on 11-SEP-2023, which is incorporated in its entirety by this reference.

TECHNICAL FIELD

[0002] This invention relates generally to the field of horticultural and agricultural automation and more specifically to new and useful systems and methods for plant-localized atmospheric water harvesting in the field of horticultural and agricultural automation.

BRIEF DESCRIPTION OF THE FIGURES

[0003] FIGURE 1 is a schematic representation of one variation of the atmospheric water harvesting system.

[0004] FIGURE 2 is a schematic representation of one variation of the atmospheric water harvesting system.

[0005] FIGURE 3 is a flowchart representation of one variation of a method for operating the atmospheric harvesting system.

[0006] FIGURE 4A is a schematic representation of one variation of the atmospheric water harvesting system.

[0007] FIGURE 4B is a schematic representation of one variation of the atmospheric water harvesting system.

[0008] FIGURE 5 is a schematic representation of one variation of the atmospheric water harvesting system.

[0009] FIGURE 6A is a schematic representation of one variation of the atmospheric water harvesting system.

[0010] FIGURE 6B is a schematic representation of one variation of the atmospheric water harvesting system.

[0011] FIGURE 7A is a schematic representation of one variation of the atmospheric water harvesting system.

[0012] FIGURE 7B is a schematic representation of one variation of the atmospheric water harvesting system.

[0013] FIGURE 7B is a schematic representation of one variation of the atmospheric water harvesting system.

[0014] FIGURE 7C is a schematic representation of one variation of the atmospheric water harvesting system.

[0015] FIGURE 7D is a schematic representation of one variation of the atmospheric water harvesting system.

[0016] FIGURE 7E is a schematic representation of one variation of the atmospheric water harvesting system.

[0017] FIGURE 7F is a schematic representation of one variation of the atmospheric water harvesting system.

[0018] FIGURE 8A is a schematic representation of one variation of the atmospheric water harvesting system.

[0019] FIGURE 8B is a schematic representation of one variation of the atmospheric water harvesting system.

[0020] FIGURE 9 is a schematic representation of one variation of the atmospheric water harvesting system.

[0021] FIGURE 10A is a schematic representation of one variation of the atmospheric water harvesting system.

[0022] FIGURE 10B is a schematic representation of one variation of the atmospheric water harvesting system.

[0023] FIGURE 10C is a schematic representation of one variation of the atmospheric water harvesting system.

[0024] FIGURE 10D is a schematic representation of one variation of the atmospheric water harvesting system.

[0025] FIGURE 11 is a schematic representation of one variation of the atmospheric water harvesting system.

[0026] FIGURE 12 is a schematic representation of one variation of the atmospheric water harvesting system.

[0027] FIGURE 13 is a flowchart representation of one variation of a method for training a local condition model.

[0028] FIGURE 14 is a flowchart representation of one variation of a method for training the water consumption model.

[0029] FIGURE 15 is one variation of a method for operating the atmospheric harvesting system.

DESCRIPTION OF THE EMBODIMENTS

[0030] The following description of embodiments of the invention is not intended to limit the invention to these embodiments but rather to enable a person skilled in the art to make and use this invention. Variations, configurations, implementations, example implementations, and examples described herein are optional and are not exclusive to the variations, configurations, implementations, example implementations, and examples they describe. The invention described herein can include any and all permutations of these variations, configurations, implementations, example implementations, and examples.

[0031] Generally, the term “can,” as utilized herein, indicates an action or attribute of the system, which may or may not be executed by or be applicable to the system depending on the implementation or embodiment of the system.

[0032] Generally, the term “include,” as utilized herein, can mean “comprise,” “consist of,” or “consist essentially of” and is not restricted to any one of the above interpretations throughout.

[0033] Generally, the term “a set of,” as utilized herein, refers to one or more of the subject objects. Additionally, the terms “first,” “second,” “third,” etc., as utilized herein, do not imply an order but simply identify multiple instances of a step or component unless an order or series is otherwise implied.

[0034] Generally, amounts of liquid water are referenced herein based on volume in milliliters. However, one of skill in the art will recognize that these amounts are interchangeable with corresponding masses of liquid water according to standard conversions.

1. Atmospheric Water Harvesting System

[0035] As shown in FIGURE 1, one variation of the atmospheric water harvesting system (hereinafter “the system 100”) associated with an associated plant includes a body 102 defining: an air inlet vent 112; an air outlet vent 114; an air conduit 116 fluidically coupling the air inlet vent 112 to the air outlet vent 114; and a housing 117. This variation of the atmospheric water harvesting system also includes: a convection subsystem 130 arranged within the housing and configured to cause ambient air to flow into the inlet vent 112, through the air conduit 116, and out of the outlet vent 114; a harvesting subsystem 140 arranged near the air conduit 116 and configured to contact the ambient air flowing through the air conduit 116; a water reservoir 150 arranged within the housing 117 and configured to collect water extracted by the harvesting subsystem 140; a water delivery structure 160 configured to release water from the water reservoir 150 toward a root system of the associated plant; a water dispensing subsystem 170

configured to control water flow from the water reservoir 150 to the water delivery structure 160; a set of ambient sensors 180 configured to measure atmospheric conditions around the associated plant; a set of delivery sensors 190 configured to measure water retention of the associated plant; and an electronic control subsystem 200.

[0036] Also shown in FIGURE 1, a planter variation of the system 100 includes a body 102 defining: a planter structure 104; a base compartment 118; a plant receptacle 120; an air inlet vent; an air outlet vent 114; and an air conduit 116 fluidically coupling the air inlet vent to the air outlet vent 114. This variation of the system 100 also includes: a convection subsystem 130 arranged within the base compartment 118 and configured to cause ambient air to flow into the air inlet vent 112, through the air conduit 116, and out of the air outlet vent 114; a harvesting subsystem 140 arranged near the air conduit 116 and configured to contact the ambient air flowing through the air conduit 116; a water reservoir 150 arranged within the base compartment 118 and configured to collect water extracted by the harvesting subsystem 140; a water delivery structure 160 configured to release water from the water reservoir 150 into the plant receptacle 120; a water dispensing subsystem 170 configured to control water flow from the water reservoir 150 to the water delivery structure 160; a set of ambient sensors 180; a set of delivery sensors 190; and an electronic control subsystem 200.

[0037] As shown in FIGURE 2, a stake variation of the system 100 includes a body defining: an air inlet vent; an air outlet vent 114; an air conduit 116 fluidically coupling the air inlet vent to the air outlet vent 114; a surface compartment 119; and a stake structure 106 comprising a soil-penetrating extrusion extending downward from the surface compartment 119. The variation of the system 100 includes: a harvesting subsystem 140 arranged near the air conduit 116 and configured to contact air flowing through the air conduit 116; a water reservoir 150 arranged within the surface compartment 119 and configured to collect water extracted by the harvesting subsystem 140; a convection subsystem 130 arranged within the surface compartment 119 and configured to cause ambient air to flow into the inlet vent, through the air conduit 116, and out of the outlet vent; a water delivery structure 160 coupled to the soil-penetrating extrusion and configured to release water from the water reservoir 150; a water dispensing subsystem 170 configured to control water flow from the water reservoir 150 to the water delivery structure 160; a set of ambient sensors 180; a set of delivery sensors 190; and an electronic control subsystem 200.

2. Method for Operating the Atmospheric Water Harvesting System

[0038] As shown in FIGURE 3, a method S100 for operating the system 100 includes: accessing regional meteorological data for a prediction period, the regional meteorological data comprising

a regional temperature time series and a regional humidity time series in Step S110; evaluating a local condition model to predict a local temperature time series and a local humidity time series over the prediction period based on the regional temperature time series and the regional humidity time series in Step S120; evaluating a harvesting performance model to predict a harvesting performance time series over the prediction period based on the local temperature time series and the local humidity time series in Step S130; evaluating a water consumption model to predict a water consumption time series for the associated plant and over the prediction period based on the local temperature time series and the local humidity time series in Step S140; calculating an operating power level time series over the prediction period based on the harvesting performance time series, the water consumption time series, and a current capacity of the water reservoir 150 in Step S150; and operating the convection subsystem 130 and/or the harvesting subsystem 140 according to a current operating power level corresponding to a current time in the operating power level time series in Step S160.

3. Applications

[0039] Generally, the system 100 executes a method S100 to autonomously and efficiently harvest water from the atmosphere and provide water to individual plants associated with each instance of the system 100, thereby obviating centralized water distribution means such as irrigation systems, indoor or outdoor plumbing, and manual watering. Additionally, by harvesting water from the atmosphere, the system 100 reduces potable and/or gray water consumption and acts as a dehumidifier in indoor environments. Also, by automating water delivery on an individual plant basis, the system 100 prevents overwatering and underwatering, which are frequent causes of premature plant death. Furthermore, the system 100 provides distilled water with low mineral content, low salt content, and neutral pH, which may improve plant health. Thus, the system 100 enables more scalable and environmentally friendly deployment of plants for agricultural, environmental, landscaping, or spatial design purposes in circumstances in which water is scarce, difficult to deploy directly to plants, or of poor quality.

[0040] the system 100 leverages onboard ambient sensors and predictive condition modeling to accurately identify times that are most efficient for atmospheric water harvesting. More specifically, the system 100 can: predict hyperlocal ambient conditions around a plant (e.g., temperature, humidity, pressure, dew point, solar intensity) over a prediction period; predict atmospheric water harvesting efficiency and plant water consumption over the prediction period; and operate an onboard harvesting subsystem 140 and convection subsystem 130 to harvest a sufficient quantity of water for the associated plant.

[0041] In one variation, the system 100 is implemented as a single- or multi-plant planter containing one or more plant receptacles 120, thereby co-locating the system 100 and the set of associated plants and enabling direct dispensation of harvested water into one or more plant receptacles 120. In one example of this variation, the system 100 is hydroponic, thereby ensuring efficient water uptake by the set of associated plants. In another example, the system 100 houses soil within each plant receptacle 120, thereby providing additional nutrients to each plant in the set of plants and expanding the types of plants that can be supported by the system 100. Thus, the system 100 can be integrated into a planter form factor commonly utilized for housing plants in indoor or outdoor environments.

[0042] In another variation, the system 100 is implemented as a stake, which can be inserted into soil near a set of associated plants, thereby further expanding the variety of plants that may be assisted by the system 100 (e.g., trees, bushes, larger plants that may not fit within a planter). In this implementation, the system 100 can utilize a soil penetrating extrusion to deliver water near the root system of the set of associated plants. Thus, the system 100 can support associated plants in many outdoor applications such as landscaping and agricultural applications.

[0043] In yet another variation, the system 100 is implemented as a plant wall including multiple plant receptacles 120 supplied by a single harvesting subsystem 140, as described in U.S. Patent 11,986,771, which is incorporated in its entirety by this reference. In this variation, the system 100 can distribute water between multiple hydroponic plants, enabling the system 100 to mitigate variations in water consumption between individual plants.

4. Body

[0044] As shown in FIGURE 1, the system 100 includes a body 102 or chassis that houses each of the components of the system 100, at least in part. More specifically, the body 102 defines openings, or apertures, and compartments that enable various functions of the system 100 including: an air inlet vent; an air outlet vent; an air conduit 116 fluidically coupling the air inlet vent to the air outlet vent 114; and a housing 117. Additionally, the body 102 provides mechanical support and thermal insulation to the internal components of the system 100. Thus, a body defines a structure corresponding to the intended application of the system 100 and can take a variety of specific forms further described below.

[0045] Generally, the body 102 can be constructed with rigid and weather and/or corrosion-resistant materials sufficient to protect and support interior components of the system 100 in the intended application of the system 100. For implementations of the system 100 intended for outdoor use, the body 102 can be constructed from aluminum, stainless steel,

ceramic, fiberglass and/or other composite materials, or rigid plastics such as high-density polyethylene.

[0046] In one implementation, the body 102 can define a set of air inlet vents arranged at various locations on the exterior surface of the body 102 to enable the ingestion of air for various functions of the system 100. In another implementation, the body 102 can define a set of air outlet vents arranged at various locations on the exterior surface of the body 102 to enable the system 100 to expel air efficiently from the system 100. Additionally, the body 102 can define an interior structure of the air conduit 116 that reduces the power needed to draw air into the air inlet vent through the air conduit 116 and out of the outlet vent.

4.1. Planter Body

[0047] As shown in FIGURE 1, in the planter variation of the system 100, the body 102 defines a planter structure 104; a base compartment 118; a plant receptacle 120; an air inlet vent; an air outlet vent 114; and an air conduit 116 fluidically coupling the air inlet vent to the air outlet vent 114. More specifically, the planter structure 104 defines: a perimeter shell around the plant receptacle 120 and a set of feet configured to raise a bottom surface of the planter structure 104 off of a supporting surface. Thus, in the planter variation, the body 102 defines a form factor similar to typical planters with sufficient interior space for each of the components of the system 100.

[0048] In the planter variation of the system 100, the body 102 can define a plant receptacle 120 characterized by an interior volume configured to contain the root system of the associated plant. The plant receptacle 120 is open on the top side of the interior volume to allow for upward growth of the associated plant within the plant receptacle 120. Various implementations of the plant receptacle 120 are further described below.

[0049] In the planter variation of the system 100, the perimeter shell structurally supports the plant receptacle 120 within its interior and can be hollow to house various components of the system 100 such as the air conduit 116, the harvesting subsystem 140, and various subcomponents of the power subsystem. For example, the perimeter shell can define a width of between 1.0 and 10.0 centimeters and a wall thickness between 1.0 and 5.0 millimeters depending on the material of the body 102 and the scale of the overall system. Thus, the perimeter shell of the planter variation of the system 100 acts as a wall that supports and protects the root system of the associated plant or set of associated plants within the plant receptacle 120 of the system 100.

[0050] Additionally, by defining the air inlet vent or the air outlet vent 114 on the upper surface of the perimeter shell, the system 100 can agitate air around the perimeter shell, causing air to

flow over the condensation plate further described below in the context of some implementations.

[0051] In the planter variation of the system 100, the set of feet raises the bottom surface of the planter structure 104 above a supporting surface to enable airflow to or from the air inlet vent or the air outlet vent 114, respectively. The set of feet can include feet of any number, shape, or thickness sufficient to raise the bottom surface of the planter structure 104 enough to facilitate airflow to or from the air inlet vent or the air outlet vent 114, respectively. Generally, implementations in which the feet are thicker and the bottom surface of the planter structure 104 is offset farther from the supporting surface of the system 100 provide greater maximum airflow to or from the air inlet vent or the air outlet vent 114, respectively, defined on the bottom surface of the planter structure 104 of the planter. In one example, the set of feet is characterized by a thickness between 1.0 and 10.0 millimeters. Additionally, the set of feet can be constructed from a high-friction material such as a rubber to prevent accidental movement of the system 100 over the supporting surface. Thus, the form of the set of feet may be selected based on the intended maximum airflow through the air inlet vent or the air outlet vent 114 located on the bottom surface of the planter structure 104.

4.1.1. Top-Down Implementation

[0052] As shown in FIGURE 1, in a top-down implementation, the body 102 defines the air inlet vent on the upper surface of the perimeter shell and routes air through the air conduit 116 toward the air outlet vent 114 on the bottom surface of the planter structure 104, thereby moving air from above the planter structure 104 to below the planter structure 104. More specifically, the body 102 defines the air inlet vent arranged on an upper surface of the perimeter shell; the air conduit 116 arranged within the perimeter shell; and the air outlet vent 114 arranged on the bottom surface of the planter structure 104. In this implementation, the convection subsystem 130 can include the convection subsystem 130 (i.e., a fan) arranged over the air outlet vent 114 to push air out of the air outlet vent 114, thereby drawing air into the air inlet vent via an induced pressure differential. Thus, in this implementation, the system 100 can draw ambient air from above the planter structure 104 toward the harvesting subsystem 140 for water harvesting.

4.1.2. Bottom-Up Implementation

[0053] As shown in FIGURE 4A, in a bottom-up implementation, the body 102 defines the air inlet vent on the bottom surface of the planter structure 104 and routes air through the air conduit 116 upward toward the air outlet vent 114 on the upper surface of the perimeter shell. More specifically, the body 102 defines: the air inlet vent arranged on the bottom surface of the planter structure 104; the air conduit 116 arranged within the perimeter shell; and the air outlet vent 114

arranged on the upper surface of the perimeter shell. In this implementation, the convection subsystem 130 is arranged over the air inlet vent and configured to pull air in through the air inlet vent and push air upward and out of the air outlet vent 114. Thus, in this implementation, the system 100 can draw ambient air from below the planter structure 104 toward the harvesting subsystem 140 for water harvesting.

[0054] As shown in FIGURE 4B, in an alternative bottom-up implementation, the system 100 includes a passive convection subsystem 130 that leverages air heated via the heat sink 147 to passively cause air to flow upward through the air conduit 116.

4.1.3. Reversible Implementation

[0055] In a reversible implementation, shown in FIGURE 5, the body 102 defines an upper inlet-outlet vent 113 and an bottom inlet-outlet vent 115 and the convection subsystem 130 is configured to drive airflow through the air conduit 116 either from the upper inlet-outlet vent 113 to the bottom inlet-outlet vent 115 or from the bottom inlet-outlet vent 115 to the upper inlet-outlet vent 113. More specifically, the body 102 defines: an upper inlet-outlet vent 113 arranged on the upper surface of the perimeter shell; the air conduit 116 arranged within the perimeter shell; and the bottom inlet-outlet vent 115 arranged on the bottom surface of the planter structure 104. In this implementation, the system 100 can operate the convection subsystem 130 to drive air in the direction that is most efficient at any given time. For example, when the supporting surface of the system 100 is cooler than the ambient air, the system 100 can operate the convection subsystem 130 to drive air from the bottom inlet-outlet vent 115 toward the top inlet-outlet vent because the cooler air near the supporting surface is closer to the dew point and therefore requires less energy to harvest water from. In another example, when the ambient air is cooler than the supporting surface, the system 100 can operate the convection subsystem 130 to drive air from the upper inlet-outlet vent 113 toward the bottom inlet-outlet vent 115 because the cooler ambient air farther from the supporting surface is closer to the dew point and therefore requires less energy to harvest water from. Thus, in this implementation, the system 100 can further increase efficiency across multiple conditions at the expense of increased complexity of the convection subsystem 130.

4.1.4. Hydroponic Plant Receptacle

[0056] As shown in FIGURE 1, in one implementation, the body 102 can define a hydroponic plant receptacle 120, which can be fluidically coupled to the water reservoir 150. In this implementation, the system 100 can include a water delivery structure 160 including a set of water apertures that enables water to freely flow between the plant receptacle 120 and the water reservoir 150, such that, when the water reservoir 150 contains greater than a threshold volume

of water, water flows from the water reservoir 150 into the plant receptacle 120. Thus, in this implementation, the body 102 can define a volume that acts as both the water reservoir 150 and the plant receptacle 120.

[0057] Alternatively, the system 100 can include a water delivery structure 160 including a nozzle configured to admit water pumped from the water reservoir 150 to the plant receptacle 120. Additionally, in this implementation, the system 100 can include a nutrient dispensing subsystem 175, further described below, to provide nutrients to the associated plant via the plant receptacle 120. Thus, in some implementations, the system 100 can control water flow between the water reservoir 150 and a hydroponic plant receptacle 120 and/or control nutrient flow into the plant receptacle 120.

4.1.5. Soil-Containing Plant Receptacle

[0058] As shown in FIGURE 6A, in one implementation, the body 102 defines a plant receptacle 120 configured to contain a solid soil mixture supporting a plant. In this implementation, the system 100 can include a water delivery structure 160 extending into the interior volume of the plant receptacle 120 to enable even absorption of water into the soil of the plant receptacle 120. In this implementation, the plant receptacle 120 can also include a catchment 162 or drain configured to return any water not retained by the soil to the water reservoir 150 to be dispersed back into the soil at a later time. Thus, in this implementation, the system 100 can support plants that cannot be grown hydroponically.

[0059] As shown in FIGURE 6B, in another implementation, the body 102 defines an ebb and flow type water delivery structure 160. In this implementation, the system 100 fills a column of water configured to permeate into the soil. As described above with respect to FIGURE 6A, the system 100 can also include a catchment 162 to return any water not absorbed by the soil to the water reservoir 150. Additionally, this ebb and flow type water delivery structure 160 can also be utilized in hydroponic implementations of the system 100. Thus, in this implementation, the system 100 can be characterized by reduced mechanical complexity of the water delivery structure 160.

4.2. Stake Body

[0060] As shown in FIGURE 2, in the stake variation of the system 100, the body 102 defines a stake-like structure with many of the components of the system 100 housed in a surface compartment 119, but also extending below ground to deliver water to the root system of an associated plant. More specifically, in the stake variation of the system 100, the body 102 defines: a surface compartment 119; a stake structure 106 including a soil-penetrating extrusion extending downward from the surface compartment 119; an air inlet vent; an air outlet vent; and

an air conduit 116 fluidically coupling the air inlet vent to the air outlet vent 114 within the surface compartment 119. Thus, in this variation of the system 100, the system 100 can be deployed to autonomously and efficiently supply water to any plant growing in soil that can be penetrated by the soil-penetrating extrusion.

[0061] In the stake variation of the system 100, the surface compartment 119 can partially or completely house the air conduit 116, the convection subsystem 130, the harvesting subsystem 140, the power subsystem, one or more ambient sensors in the set of ambient sensors 180, one or more delivery sensors in the set of deliver sensors, the water reservoir 150, the water dispensing subsystem 170, and/or the electronic control subsystem 200. Additionally, the body 102 can define the air inlet vent and the air outlet vent 114 on the exterior surfaces of the surface compartment 119. Thus, even upon insertion of the system 100 into the soil, many of the components will remain above ground for easier access and maintenance.

[0062] In the stake variation of the system 100, the body 102 defines a soil-penetrating extrusion extending downward from the surface compartment 119. The soil-penetrating extrusion can define a sharp distal end to enable the system 100 to be pressed into the soil during deployment. Alternatively, the soil-penetrating extrusion can define a rounded or blunt distal end and can be deployed to a soil location via drilling of a guide hole sufficient to house the soil-penetrating extrusion. Thus, the soil-penetrating extrusion enables the water dispensing subsystem 170 to dispense harvested water closer to the root system of an associated plant.

[0063] In one implementation of the stake variation, the system 100 can include a soil-penetrating extrusion capable of articulating or bending to dispense water at a location closer to the root system of the associated plant that is horizontally displaced from the entry location of the soil-penetrating extrusion in the ground. Thus, in this implementation, the system 100 can dispense water closer to the root system of the associated plant without interfering with the growth of the target plant.

[0064] In another implementation, the soil-penetrating extrusion can partially or completely house the water reservoir 150, which can define a volume that extends downward from the surface compartment 119 into the soil-penetrating extrusion.

[0065] In yet another implementation, the soil-penetrating extrusion can house the water dispensing subsystem 170 to dispense water beneath the surface of soil via the water delivery structure 160, which can extend horizontally from the soil-penetrating extrusion. In this implementation, the water delivery structure 160 can include extendible capillaries that can be deployed from the soil-penetrating extrusion via electromechanical or mechanical actuation (e.g., via solenoids, electric motors). In this implementation, the extensible capillaries define small

holes configured to dispense water from the capillaries when the water is under pressure. Thus, in this implementation, the system 100 can dispense water over a wider horizontal area.

5. Convection Subsystem

[0066] As shown in FIGURE 1, the system 100 includes a convection subsystem 130 configured to actively and/or passively cause convection and/or airflow around a heat sink 147 for a thermoelectric condenser 141 and/or around a condensation surface 148 or capture medium 145. The system 100 can include a heat sink 147 in any implementation of the system 100 including a thermoelectric condenser 141, however, the heat sink 147 is not shown in all drawings for ease of illustration. Thus, the convection subsystem 130 provides convective airflow to the harvesting subsystem 140 to support the water harvesting functionality of the system 100.

[0067] In an active implementation, the convection subsystem 130 is configured to drive air into the air inlet vent through the air conduit 116 and out of the outlet vent to provide air from which the system 100 can harvest water and/or to provide air to a heat sink 147 for the harvesting subsystem 140. More specifically, in the active implementation, the system 100 includes a convection subsystem 130 arranged within the housing 117 and configured to cause ambient air to flow into the inlet vent, through the air conduit 116, and out of the outlet vent. In the planter variation, the system 100 can include a convection subsystem 130 arranged within the base compartment 118 and configured to cause ambient air to flow into the inlet vent, through the air conduit 116, and out of the outlet vent. In an active implementation of the stake variation, the system 100 includes a convection subsystem 130 arranged within the surface compartment 119 and configured to cause ambient air to flow into the inlet vent, through the air conduit 116, and out of the outlet vent. Thus, in the active implementation of each variation the convection subsystem 130 is arranged to ensure air comes into contact with the harvesting subsystem 140 by flowing through the air conduit 116.

[0068] In a passive implementation, the convection subsystem 130 includes specific structures or shaping of the body 102 of the system 100 that exposes surfaces configured to operate via convection (e.g., such as the heat sink 147 and/or a condensation surface 148). More specifically, in the passive implementation, the convection subsystem 130 includes a passive convection structure configured to facilitate convection about a condensation surface 148. Additionally or alternatively, in the passive implementation, the convection subsystem 130 includes a passive convection structure configured to facilitate convection about a heat sink 147. Thus, in the active implementation of each variation the convection subsystem 130 is arranged to ensure air comes into contact with the harvesting subsystem 140 by flowing through the air conduit 116.

[0069] In one implementation, the convection subsystem 130 includes an electrically powered fan arranged across the air inlet vent and/or the air inlet vent to draw air into the air inlet vent and push air out of the air outlet vent 114. In one example of this implementation, the convection subsystem 130 includes an electrically powered fan characterized by a blade profile configured to drive air in one direction. Alternatively, the fan is configured to rotate both clockwise and counterclockwise by defining a reversible blade profile that is characterized by high efficiency when rotating in either direction. However, the convection subsystem 130 can include any other air moving device or mechanism.

6. Harvesting Subsystem

[0070] As shown in FIGURE 1, the system 100 includes a harvesting subsystem 140 configured to extract water from ambient air and/or air flowing through the air conduit 116 to harvest water for the water reservoir 150. More specifically, the harvesting subsystem 140 is arranged near the air conduit 116 and configured to contact the ambient air flowing through the air conduit 116. In various implementations, the harvesting subsystem 140 can harvest water from ambient air or air flowing through the air conduit 116 via temperature induced condensation, high-voltage forced condensation, and/or via a physical or chemical sorbent. Thus, the system 100 can operate the harvesting subsystem 140 and/or the convection subsystem 130 (for implementations including an active convection subsystem 130) to harvest water from ambient air while utilizing under one watt of power.

[0071] In implementations of the harvesting subsystem 140 including a thermoelectric condenser 141, thermoelectric cooler, or Peltier device, the system 100 can include a Peltier device characterized by a thermal power proportional to the rate of water required for intended associated plants. In a small planter implementation (e.g., a planter 10 centimeters in diameter), the thermoelectric condenser 141 is characterized by a thermal power of less than one watt. However, larger implementations of the system 100 can include thermoelectric condensers 141 characterized by higher thermal power.

[0072] In one implementation, shown in FIGURE 7A the harvesting subsystem 140 includes a thermoelectric condenser 141 (i.e., a Peltier device) configured to utilize air flowing through the air conduit 116 as a heat sink 147. In this implementation, the harvesting subsystem 140 includes a cold side 142 (i.e., a cold plate of the Peltier device) exposed to ambient air, such as arranged on the interior surface of the perimeter shell in the planter variation or on an exterior surface of the surface compartment 119 in the stake variation. In this implementation, a hot side 143 of the Peltier device is positioned along a wall of the air conduit 116 to transfer heat extracted from the cold side 142 to air flowing through the air conduit 116. In one example of this implementation,

shown in FIGURE 7B, the cold side 142 is positioned along an interior rim of the perimeter shell 105 near the inlet vent to increase the amount of ambient air exposed to the cold side 142 and slightly cooling the air prior to being pulled into the air conduit 116 and flowing through the heat sink 147. Thus, in this implementation, the thermoelectric condenser transfers heat away from the cold side 142 toward the air conduit 116 to cause the cold side 142 to drop below the current dew point of the ambient air, thereby causing condensation on the surface of the cold side 142. Condensed water can then drain under the force of gravity toward the water reservoir 150.

[0073] In another implementation, shown in FIGURES 7C, the harvesting subsystem 140 includes a thermoelectric condenser 141 comprising a cold side 142 contacting air flowing through the air conduit 116. More specifically, in this implementation, the system 100 drives air through the air conduit 116 toward a cold plate or cold side 142 of the Peltier device causing condensation on the surface of the cold side 142. The system 100 then drives the cooler air through the hot side 143 of the Peltier device, thereby increasing the capacity of the air to absorb heat from the heat sink 147.

[0074] In yet another implementation, shown in FIGURE 7D, the system 100 includes a split or divided air conduit 116 where inlet air is funneled toward the cold side 142 of the Peltier device and the hot side 143 of the Peltier device in parallel to provide a consistent flow of water vapor to condense at the cold side 142 while also flowing over the hot side 143 of the thermoelectric condenser 141 and/or through the heat sink 147 of the thermoelectric condenser 141.

[0075] In yet another implementation, the harvesting subsystem 140 includes a capture medium 145 or sorbent such as a metal organic framework (hereinafter “MOF”) arranged within the air conduit 116 and configured to adsorb water vapor from inlet air flowing through the air conduit 116. In this implementation, the harvesting subsystem 140 can apply heat to the capture medium 145 to desorb adsorbed water into the water reservoir 150. Alternatively, the system 100 can operate the convection subsystem 130 in cooperation with the harvesting subsystem 140 to reduce the pressure within the air conduit 116, causing vacuum desorption of water vapor from the capture medium 145. Thus, the harvesting subsystem 140 can utilize capture media 145, such as MOFs, to efficiently capture water vapor from inlet air flowing through the air conduit 116.

[0076] In yet another implementation, shown in FIGURE 7E, the harvesting subsystem 140 can include a capture medium 145 arranged within the air conduit 116 and acting as the heat sink 147 for the thermoelectric condenser 141. In this implementation, the system 100 can operate the convection subsystem 130 to cause air to flow through the capture medium 145 in a sorption phase. Subsequently, the system 100 can operate the thermoelectric condenser 141, causing condensation on the cold side 142 of the thermoelectric condenser 141 and desorption at the

capture medium 145 as the hot side 143 of the Peltier device. Thus, in this implementation, the condenser system utilizes waste heat from the Peltier device or thermoelectric condenser 141 to extract water from the capture medium 145, thereby increasing overall condensation efficiency.

[0077] In yet another implementation, FIGURE 7F the harvesting subsystem 140 includes an electrohydrodynamic (hereinafter “EHD”) condenser 146 configured to polarize water vapor particles to encourage droplet formation on surfaces via a high-voltage electric field. In this implementation, the harvesting subsystem 140 can include an EHD condenser 146 located near to (e.g., within a few millimeters of a condensing surface within the air conduit 116). In this implementation, the system 100 can operate the convection subsystem 130 to slow the flow rate of air through the air conduit 116 to provide sufficient time for high-voltage forced condensation within the air conduit 116. In another example of this implementation, the system 100 can operate the harvesting subsystem 140 to recapture water vapor released by another process such as desorption of water vapor from a MOF or other capture medium 145. Thus, the harvesting subsystem 140 can include an EHD condenser 146 to improve water retention or harvesting efficiency of other water harvesting processes.

7. Water Reservoir

[0078] As shown in FIGURE 1, the system 100 includes a water reservoir 150 or catchment basin configured to receive and store water harvested by the harvesting subsystem 140. More specifically, the system 100 can include a water reservoir 150 arranged within the housing 117 and configured to collect water extracted by the harvesting subsystem 140 via a water conduit. In the planter variation, the water reservoir 150 is arranged within the base compartment 118. In the stake variation, the water reservoir 150 is arranged within the surface compartment 119 and/or the soil-penetrating extrusion. Thus, the system 100 includes a water reservoir 150 configured to receive water from the harvesting subsystem 140.

[0079] Generally, the water reservoir 150 defines a funneled or sloped bottom to enable consistent access to water in the reservoir by the water dispensing subsystem 170 via a port at the bottom of the water reservoir 150. Additionally, the water reservoir 150 can include a pressure transducer arranged at the bottom of the funneled or sloped bottom to accurately measure the water level within the water reservoir 150 to inform execution of the method S100. Thus, the sloped bottom of the water reservoir 150 enables consistent water drainage and measurement from the water reservoir 150.

[0080] In one implementation, the water reservoir 150 is configured to receive water from multiple components of the harvesting subsystem 140 via multiple water conduits. For example, the water reservoir 150 can receive water that condensed on the condensation surface 148 of the

cold side 142 of a thermoelectric condenser 141 or Peltier device and simultaneously from a capture medium 145, including a MOF. Additionally, the water reservoir 150 can receive water via a water conduit or aperture from the plant receptacle 120 in the planter variation. For example, the water receptacle can receive water not absorbed by the associated plant that drains out of soil in the plant receptacle 120. In another example, the water reservoir 150 can receive water from an open catchment configured to receive rainwater to supplement the water harvested by the harvesting subsystem 140. Thus, the water reservoir 150 can be fluidically connected to multiple sources of water within the system 100.

8. Water Delivery Structure

[0081] Generally, the system 100 includes a water delivery structure 160 configured to release water from the water reservoir 150 toward a root system of the associated plant. Thus, the water delivery structure 160 enables the physical distribution of water such that the water can be absorbed by the associated plant.

[0082] In the planter variation, as shown in FIGURE 1, the system 100 includes a water delivery structure 160 configured to release water from the water reservoir 150 into the plant receptacle 120. As shown in FIGURE 8A, in implementations of the planter variation utilizing a hydroponic plant receptacle 120, the water delivery structure 160 can be implemented as an aperture or opening at the top of the water reservoir 150 that enables water to flow from the water reservoir 150 into the plant receptacle 120 (and vice versa) when the water volume exceeds the capacity of the water reservoir 150. In this implementation, the water delivery structure 160 prevents excessive evaporation of water within the water reservoir 150 by separating the water in the water reservoir 150 from the plant receptacle 120, which is characterized by a greater exposed surface area. Alternatively, as shown in FIGURE 8B, the water reservoir 150 can serve a dual role as the plant receptacle 120, such that the associated plant is located within the water reservoir 150, thereby obviating any need for a water delivery structure 160. As shown in FIGURE 6A and FIGURE 6B, in implementations of the planter variation configured to house soil within the plant receptacle 120, the water deliver structure can include an extrusion, such as a vertical column, into the interior volume of the plant receptacle 120 configured to release water within the soil volume housed in the plant receptacle 120, thereby improving water retention by the soil and water uptake by the associated plant housed within the plant receptacle 120.

[0083] In the stake variation, the system 100 can include a water delivery structure 160 coupled to and/or extending from the soil-penetrating extrusion and configured to release water from the water reservoir 150 into soil surrounding the soil-penetrating extrusion. In this implementation,

the water delivery structure 160 can include a set of capillary extensions defining dispensing holes enabling the system 100 to deliver water at locations horizontally displaced from the soil-penetrating extrusion. Additionally or alternatively, the system 100 can include a water delivery structure 160 including a series of holes along the length of the soil-penetrating extrusion, thereby enabling the system 100 to deliver water to the soil surrounding the soil-penetrating extrusion directly.

9. Water Dispensing Subsystem

[0084] As shown in FIGURE 1, the system 100 can include a water dispensing subsystem 170 configured to control water flow from the water reservoir 150 to the water delivery structure 160. In the planter variation, the water dispensing subsystem 170 is configured to control water flow from the water reservoir 150 to the water delivery structure 160. In the stake variation, the water dispensing subsystem 170 is configured to control water flow from the water reservoir 150 to the water delivery structure 160. Thus, the water dispensing subsystem 170 receives commands from the electronic control subsystem 200 and, in response, causes water to flow from the water reservoir 150 toward the associated plant via the water delivery structure 160.

[0085] Generally, the water dispensing subsystem 170 can include any number of electromechanical valves, tubes, pipes, and/or pumps to control water flow from the water reservoir 150 and through the water delivery structure 160. Alternatively, in implementations in which the water reservoir 150 also acts as the plant receptacle 120, the system 100 can exclude a water dispensing subsystem 170 and control the presence of water within the plant receptacle 120 by operating the harvesting subsystem 140 alone.

[0086] In one implementation, the water dispensing subsystem 170 includes a low-power, low-volume pump, such as a diaphragm pump, a peristaltic pump, a micro direct current pump, a piezoelectric pump, a gear pump, and/or any pump satisfying voltage power draw and volume accuracy specifications. However, the water dispensing subsystem 170 can include any type of pump appropriate for the head height and target flow rates for the system 100. Thus, the system 100 can dispense small volumes of water sufficient to maintain plant health without substantially overshooting or undershooting the target volume.

10. Nutrient Dispensing Subsystem

[0087] As shown in FIGURE 9, in some implementation, the system 100 can also include a nutrient dispensing subsystem 175 configured to draw nutrients from a nutrient cartridge 176 into the flow of water dispensed via the water dispensing subsystem 170. Alternatively, the nutrient dispensing subsystem 175 can dispense nutrients directly into the water reservoir 150. Thus, the system 100 can provide nutrients to the associated plant in implementations including a

hydroponic plant receptacle 120 or in instances in which the soil within the plant receptacle 120 or surrounding the soil-penetrating extrusion does not contain sufficient nutrients for the associated plant or set of plants.

[0088] Generally, the nutrient cartridge 176 includes nutrients dissolved in solution including, but not limited to, nitrogen (e.g., in the form of nitrate or ammonium ions), phosphorus (e.g., in the form of phosphate ions), ionic potassium, ionic calcium, ionic magnesium, sulfur (e.g., in form of sulfate ions), iron (e.g., chelated iron), ionic manganese, ionic zinc, ionic copper, boron (e.g., in the form of boric acid), molybdenum (e.g., in the molybdate), chloride, and/or ionic nickel. The nutrient cartridge 176 can also include pH adjusters, beneficial microbes (bacteria or fungi), and/or chelating agents.

[0089] In one implementation, the nutrient dispensing subsystem 175 can include an electromechanical actuator such as a solenoid or linear actuator configured to cause micro-volumes of the nutrient solutions to enter water traveling through the water dispensing subsystem 170 or water reservoir 150. In this implementation, the nutrient dispensing subsystem 175 is characterized by dose rate between 5 and 100 milliliters per minute.

11. Power Subsystem

[0090] Generally, the system 100 includes a power subsystem configured to provide electrical power to various electromechanical components of the system 100 including the convection subsystem 130, the harvesting subsystem 140, the water dispensing subsystem 170, the nutrient dispensing subsystem 175, the set of ambient sensors 180, the set of delivery sensors 190, and the electronic control subsystem 200. Thus, the system 100 can effectively execute the method S100 utilizing power derived from the power subsystem.

[0091] In one implementation, the power subsystem can include a photovoltaic power source 210 and a battery 212. More specifically, the power subsystem can include a photovoltaic power source 210 arranged on an exterior surface of the body 102. As shown in FIGURE 10A, in the planter variation, the photovoltaic power source 210 (e.g., panel) is arranged on an outer surface of the perimeter shell of the planter structure 104, such that the photovoltaic power source 210 is likely to be exposed to sunlight. As shown in FIGURE 10B, in the stake variation, the photovoltaic power source 210 is arranged on an outer surface of the surface compartment 119, such that the photovoltaic power source 210 is likely to be exposed to sunlight. Generally, the photovoltaic power source 210 can include a photovoltaic panel characterized by a maximum power generation between 3 and 30 watts when in direct sunlight (e.g., for a system about 10 centimeters in diameter). However, the power subsystem can include a photovoltaic source with a greater power capacity for larger implementations of the system 100. Thus, in this

implementation, the system 100 can remain off-grid and harvest water via energy produced by the power subsystem.

[0092] In this implementation, the battery 212 is configured to receive power from the photovoltaic power source 210 and store this power for subsequent use by the system 100. Thus, the system 100 can utilize the battery 212 to delay power consumption until conditions are favorable for atmospheric water harvesting by the harvesting subsystem 140.

[0093] As shown in FIGURE 10C, in another implementation, the power subsystem includes a wireless power receiver 214 and/or a battery 212. In this implementation, the wireless power receiver 214 is configured to receive wireless power via a directed electromagnetic field generated by a base station. More specifically, in this implementation, the wireless power receiver 214 is configured to receive a maximum power between 0.5 watts and 60 watts. In this implementation, the base station can power multiple instances of the system 100 from a distance. In one example of this implementation, the power subsystem also includes a battery 212 to store energy received via the wireless power receiver 214, thereby enabling the system 100 to operate when not currently receiving power via the wireless power receiver 214.

[0094] As shown in FIGURE 10D, in yet another implementation, the power subsystem includes a wired power connection 216 and/or a battery 212 to enable the system 100 to operate when unplugged from an external power source. In one example of this implementation, the power subsystem includes a USB connection, thereby enabling charging via widely available USB cables. In another example of this implementation, the power subsystem is configured with two or more power ports, thereby enabling users to “daisy-chain” multiple instances of the system 100 in series, connected via other instances of the system 100 to an external power source. Thus, in this implementation, the power subsystem can access readily available power from an external power source and/or store this power for later use when disconnected from the external power source.

[0095] However, the power subsystem can include any additional or alternative power sources to those described above.

12. Ambient and Internal Sensors

[0096] As shown in FIGURE 11, the system 100 includes a set of ambient sensors 180 configured to detect conditions in the immediate environment of the system 100. More specifically, the set of ambient sensors 180 can include but is not limited to: an ambient temperature sensor 181, an ambient humidity sensor 182 (e.g., a relative humidity sensor or an absolute humidity sensor), an ambient pressure sensor 183 (i.e., a barometer), and/or an ambient light sensor 184. Additionally, the system 100 can include a set of internal sensors configured to

detect conditions within the device, which may affect the operating efficiency of the harvesting subsystem 140. More specifically, the set of internal sensors can include: an air conduit temperature sensor, an air conduit humidity sensor, and/or an air conduit pressure sensor. The set of internal sensors can also include a pressure transducer arranged within the water reservoir 150 and configured to detect the current capacity of the water reservoir 150. Thus, the system 100 includes sensors configured to measure hyperlocal conditions around the associated plant to inform the electronic control subsystem 200 in execution of the method S100.

[0097] Generally, the system 100 can include temperature sensors, such as thermocouples, thermistors, semiconductor temperature sensors or integrated circuit temperature sensors, infrared temperature sensors, bimetallic temperature sensors, and/or any other type of temperature sensor characterized by a temperature accuracy between ± 0.25 and ± 2.5 degrees, thereby enabling the system 100 to operate the thermoelectric implementations of the harvesting subsystem 140 to lower the temperature of the cold side 142 to below the current dew point. The system 100 can include humidity sensors, such as capacitive humidity sensors, resistive humidity sensors, thermal conductivity humidity sensors, optical humidity sensors, gravimetric humidity sensors, infrared humidity sensors, and/or any other type of humidity sensors characterized by a range between 0% and 100% relative humidity and a humidity accuracy between $\pm 0.5\%$ and $\pm 10\%$ relative humidity. The system 100 can include pressure sensors, such as capacitive pressure sensors, piezoresistive pressure sensors, piezoelectric pressures sensors, resonant pressure sensors, optical pressure sensors, and/or any other pressure sensors characterized by a pressure accuracy between ± 0.25 and ± 1.5 kilopascals.

[0098] The set of ambient sensors 180 and the set of internal sensors are each electrically coupled and configured to transmit and/or receive digital or analog signals to and from the electronic control subsystem 200. Thus, the electronic control subsystem 200 can receive sufficient data to inform execution of the method S100 via the set of ambient sensors 180 and the set of internal sensors.

13. Delivery Sensors

[0099] Generally, the system 100 can include a set of delivery sensors 190 configured to detect the state of the associated plant in order to determine whether water has been successfully delivered to the associated plant via the dispensing subsystem and the delivery structure. Thus, the system 100 can utilize the set of delivery sensors 190 in cooperation with the set of ambient sensors 180 and the set of internal sensors to train the water consumption model.

[0100] In one implementation, the set of delivery sensors 190 includes a soil moisture sensor 191 configured to detect a moisture content in soil surrounding a root system of the associated plant.

Generally, the set of delivery sensors 190 can include soil moisture sensors, such as capacitance moisture sensors, time domain reflectometry sensors, frequency domain reflectometry sensors, gypsum block sensors, tensiometers, gravimetric sensors, and/or any other type of soil moisture sensor.

[0101] In another implementation, the set of delivery sensors 190 can include an additional pressure transducer configured to measure the mass of the water within the plant receptacle 120 and/or the growth of the associated plant over time.

[0102] In yet another implementation, the set of delivery sensors 190 includes a flow meter to precisely measure water dispensed and, by proxy, water consumed by the associated set of plants. The set of delivery sensors 190 can include any type of flow meter suitable for the range of flow rates specified by the water dispensing subsystem 170. Thus, the system 100 can verify the volumes of water dispensed by the water dispensing system and more accurately measure the water consumed by the set of associated plants.

[0103] In yet another implementation, the set of delivery sensors 190 can include an image sensor or camera configured to capture images of the associated plant to estimate the size (volume and/or mass) and/or water consumption of the target plant. In one example of this implementation, the system 100 can access images from an image-capable user device, such as a smartphone via a local or wide area network. Thus, in this implementation, the system 100 can leverage image data to inform the water consumption model for the associated plant.

14. Electronic Control Subsystem

[0104] As shown in FIGURE 12, the system 100 can include an electronic control subsystem 200 configured to: receive data from the set of ambient sensors 180, the set of internal sensors, the set of delivery sensors 190, the convection subsystem 130, the harvesting subsystem 140, and/or the power subsystem; and operate the convection subsystem 130 and/or the harvesting subsystem 140 according to the method S100. More specifically, the electronic control subsystem 200 includes a processing device 202 (i.e., a local or onboard processing device 202). Additionally, or alternatively, the electronic control subsystem 200 can include remote processing devices 204 (i.e., remote servers) communicating with the local processing device 202 over a wide- or local-area network. Thus, the electronic control subsystem 200 is a local or distributed computer system capable of executing Steps of the method S100.

14.1. Data Access

[0105] Generally, in order to calculate a current operating power level, the system 100 can access regional meteorological data to inform the local condition model of upcoming regional conditions that can be correlated to predicted hyperlocal conditions around the associated plant,

thereby enabling the system 100 to predict efficient times and operational power levels at which to harvest water from the atmosphere. More specifically, the system 100 can access regional meteorological data for a prediction period, wherein the regional meteorological data includes a regional temperature time series and a regional humidity time series in Step S110. A meteorological service capable of issuing meteorological predictions proximal to (e.g., within the same city, town, neighborhood) may make the regional meteorological data accessible over a local or wide area network. The system 100 can then access the regional meteorological data via the local or wide area network. Thus, the system 100 can leverage regional meteorological predictions to predict hyperlocal meteorological conditions.

[0106] In one implementation, the system 100 can access regional meteorological data represented as temperature time series, a humidity time series, a pressure time series, and/or a dew point time series. In this implementation, each time series defines a data point interval of 24 hours, 12 hours, one hour, 30 minutes, 15 minutes, 10 minutes, one minute or any other data point interval. Thus, the system 100 can utilize low- or high-resolution data to inform operating power level settings.

[0107] The system 100 can select a prediction period based on the historical reliability of predictive meteorological data for the region in which the system 100 is located. For example, in regions with more predictable meteorological conditions, the system 100 can utilize a longer prediction period (e.g., two weeks, one month), while, in regions with less predictable meteorological conditions, the system 100 can utilize a shorter prediction period (e.g., three days, one week). Thus, the system 100 can adjust the prediction period based on the historical accuracy of meteorological predictions in the region.

14.2. Local Condition Model

[0108] Generally, the system 100 can utilize a local condition model to predict a time series of hyperlocal conditions (i.e., within the immediate vicinity of the associated plant), which more accurately inform the most efficient operating power level setting for the system 100. More specifically, the system 100 can evaluate a local condition model to predict a local temperature time series and a local humidity time series over the prediction period based on the regional temperature time series and the regional humidity time series in Step S120. As shown in FIGURE 13, in one implementation, the system 100 can also train the local condition model by: accessing ambient data collected by the set of ambient sensors 180 over a training period in Step S122; accessing regional meteorological data for the training period in Step S124; and training the local condition model based on the ambient data and the regional meteorological data in Step S126. In one example of this implementation, the system 100 can continue to train the local

condition model during operation by repeatedly executing Steps S122, S124, and S126. Thus, the system 100 leverages hyperlocal meteorological data from the set of ambient sensors 180 to train an accurate local condition model that transforms regional meteorological predictions into local meteorological predictions.

[0109] In one implementation, the system 100 can access ambient data collected by the set of ambient sensors 180 including an ambient temperature training time series, an ambient humidity training time series, an ambient pressure training time series, a dew point training time series, a solar intensity training time series, and/or any other time series data available from the set of ambient sensors 180.

[0110] In another implementation, the system 100 can access supplemental information characterizing the physical setting of the system 100. For example, the system 100 can access supplemental information including an indoor-outdoor categorization, an HVAC system categorization (for indoor locations), HVAC set temperature, HVAC set humidity, the geographic coordinates of the system 100 or any other information relevant to the local conditions around the system 100. The system 100 can access the supplemental information directly from devices connected over a local or wide area network or can detect the supplemental information directly via classification of ambient sensor data. For example, the system 100 can identify an indoor-outdoor categorization, an HVAC system categorization, HVAC set temperature, HVAC set humidity, based on ambient sensor data and regional meteorological data via specific pre-trained classifiers. Additionally or alternatively, the system 100 can receive user inputs defining the aforementioned supplemental information.

[0111] In yet another implementation, the system 100 can utilize the solar intensity training time series and the geographic coordinates of the system 100 to more accurately predict local solar intensity (e.g., via a physical simulation of obstructions to the sun in the vicinity of the system 100).

[0112] The system 100 can train the local condition model by executing supervised learning algorithms based on the regional meteorological data over the training period (which the system 100 can interpolate or otherwise normalize for comparison to the ambient data detected by the system 100), the ambient data over the training period, and/or the supplemental information. The system 100 can train and/or evaluate a local condition model including linear regression models, time series models, random forest models, gradient boosting machines, recurrent neural networks, long short-term memory networks, convolutional neural networks, or any other machine learning model.

[0113] Upon training the local condition model or upon accessing a pre-trained local condition model, the system 100 can evaluate the local condition model by inputting a regional time series of meteorological data. The system 100 can then produce a corresponding local time series of meteorological data that is significantly more accurate than the predicted regional meteorological conditions.

14.3. Harvesting Performance Model

[0114] The system 100 can evaluate a harvesting performance model to predict the operating efficiency of the harvesting subsystem 140 and the convection subsystem 130 when harvesting water from the atmosphere over a range of operating power levels for a given set of local conditions. More specifically, the system 100 can evaluate a harvesting performance model to predict a harvesting performance time series over the prediction period based on the local temperature time series and the local humidity time series in Step S130. In particular, the system 100 can evaluate the harvesting performance model to predict the harvesting performance time series over the prediction period based on the local temperature time series and the local humidity time series, the harvesting performance time series including a time series of harvesting efficiency versus water production rate functions. Thus, the system 100 can utilize the accurate predicted local conditions output by the local condition model to identify the most efficient times and operating power level settings over the prediction period.

[0115] In one implementation, the system 100 can, for each time interval in the local temperature time series and the local humidity time series, evaluate the harvesting performance model based on at least a predicted local temperature and a predicted local humidity for the time interval. In one example, the system 100 can then output, based on the harvesting performance model, a performance function indicating the predicted harvesting efficiency in milliliters of water per watt and the water production rate in milliliters per unit time. In another example, the system 100 outputs a parametric performance function, wherein both the predicted harvesting efficiency and the predicted water production rate are represented as functions of operating power level expressed in watts. Thus, upon evaluating the harvesting performance model over the prediction period, the system 100 can utilize the time series of performance functions to identify an operating power level schedule for each time interval that maximizes efficiency while generating sufficient water for the associated plant.

[0116] The system 100 can access a harvesting performance model based on empirical performance data characterizing the operation of the system 100 at various temperatures, humidities, pressures, dew points, and solar intensities (e.g., a lookup table or a regression-based model). Additionally or alternatively, the system 100 can access a harvesting performance model

derived in part from a physical simulation of the harvesting subsystem 140 and/or the convection subsystem 130 to predict operating efficiencies and water output based on the aforementioned local conditions data. Thus, the harvesting performance model can leverage empirical performance data and simulations such as computational fluid dynamic simulations including multiphase flow models, direct numerical simulation via Navier-Stokes equations, phase field models, lattice Boltzmann method, Monte Carlo simulations or any other applicable simulation.

[0117] Therefore, upon execution of the harvesting performance model over the prediction period, the system 100 generates, for each time interval of the prediction period, a performance function indicating predicted operating efficiency and predicted water production rate for a range of operating power levels.

14.4. Water Consumption Model

[0118] Generally, the system 100 evaluates a water consumption model to identify the amount of water to harvest from the atmosphere in order to satisfy the requirements of the associated plant, thereby establishing a quantity of water to be generated by the system 100 for each time interval in the prediction period. More specifically, the system 100 can evaluate a water consumption model to predict a water consumption time series for the associated plant over the prediction period based on the local temperature time series and the local humidity time series in Step S140. As shown in FIGURE 14, in one implementation, the system 100 can train the water consumption model for the specific associated plant of the system 100. More specifically, the system 100 can: access delivery data collected by the set of delivery sensors 190 over a training period in Step S142; access ambient data for the training period in Step S144; and train the water consumption model based on the delivery data and the ambient data for the training period in Step S146. In one example of this implementation, the system 100 can continue to train the water consumption model during operation by repeatedly executing Steps S142, S144, and S146.

[0119] In one implementation, the system 100 can access delivery data and ambient data collected by the set of delivery sensors 190 and the set of ambient sensors 180 respectively including an ambient temperature training time series, an ambient humidity training time series, an ambient pressure training time series, a dew point training time series, a solar intensity training time series, a water consumption training time series (e.g., based on delivery rates of the water dispensing subsystem 170 over the training period), a water evaporation training time series (e.g., based on changes in the capacity of the water reservoir 150 not attributed to delivery of water to the associated plant), a plant mass time series (e.g., derived from pressure transducers measuring the weight of the associated plant in the plant receptacle 120), a plant volume time series (e.g., based on image data capturing the associated plant), a nutrient delivery training time

series, a soil moisture training time series, a soil nutrient content training time series, and/or any other time series data available from the set of ambient sensors 180, from the set of delivery sensors 190, or derived based on these time series data.

[0120] In another implementation, the system 100 can access supplemental information characterizing the physical setting of the system 100 and, therefore, by proxy, the associated plant. For example, the system 100 can access supplemental information including an indoor-outdoor categorization of the associated plant, the geographic coordinates of the associated plant, species classification of the associated plant, age or maturity classification of the target plant, a soil type classification for the soil surrounding the associated plant and/or any other information relevant to the local conditions around the associated plant. Thus, the system 100 can utilize these features to inform the water consumption model. Additionally, the system 100 can leverage data from other growth examples of the same or similar species of plant in various conditions. The system 100 can access the supplemental information directly from devices connected over a local or wide area network or can detect the supplemental information directly via classification of ambient sensor data or delivery sensor data. For example, the system 100 can identify the indoor-outdoor categorization of the associated plant, the species classification of the associated plant, the soil type classification via specific pre-trained classifiers. Additionally or alternatively, the system 100 can receive user inputs defining the aforementioned supplemental information.

[0121] In yet another implementation, the system 100 can utilize biological, domain-specific simulations of plant water consumption and plant growth informed by the delivery data and the ambient data to more accurately the water consumption of the plant for various conditions.

[0122] The system 100 can train the water consumption model by executing supervised learning algorithms based on the ambient data time series and the delivery data time series over the training period, and/or the supplemental information. The system 100 can train and/or evaluate a water consumption model including linear regression models, time series models, random forest models, gradient boosting machines, recurrent neural networks, long short-term memory networks, convolutional neural networks, or any other known machine learning model.

[0123] Upon training the water consumption model or upon accessing a pre-trained local condition model, the system 100 can evaluate the water consumption model based on predicted local meteorological data (at least the predicted local temperature time series and the predicted local humidity time series) to generate a rate of water consumption of the plant (e.g., in milliliters per unit time) for each time interval over the prediction period.

14.5. Power Production and Storage Model

[0124] As shown in FIGURE 15, in implementations of the system 100s including a power subsystem configured to draw power from the environment (i.e., a power subsystem including a photovoltaic panel and battery 212), the system 100 can evaluate a power production and storage model based on the predicted local condition data to predict the power generated for each time interval of the prediction period. More specifically, the system 100 can evaluate a power production and storage model to predict a power production time series over the prediction period in Step S170. Thus, in this implementation, the system 100 can accurately adjust operating power levels based on expected power generation and current power stored by the battery 212.

[0125] The system 100 can evaluate a power production and storage model based on a predicted local solar intensity time series for the system 100. The system 100 can evaluate a pre-trained power production and storage model based on empirical data correlating the power produced by the photovoltaic panel over a range of measured solar intensities. Additionally, the power production and storage model can account for the power draw of the system 100 for subsystems not including the harvesting subsystem 140 and the convection subsystem 130 and the efficiency of the battery 212 over time based on empirical data describing the performance of the system 100 overall (e.g., circuit power leakage, battery 212 self-discharge rate). Thus, the system 100 can accurately model the power demands of the system 100 over the prediction period independent of the operating power level of the system 100 over the prediction period.

14.6. Operating Power Level Calculation

[0126] Upon obtaining the harvesting performance time series and the water consumption time series and accessing the current capacity of the water reservoir 150 and/or the maximum capacity of the water reservoir 150, the system 100 can calculate a schedule of operating power levels for each time interval of the prediction period that satisfies the water demands of the associated plant while preserving at least a reserve capacity of water in the reservoir, thereby ensuring that the plant will survive for the duration of the prediction period. More specifically, the system 100 can calculate an operating power level time series over the prediction period based on the harvesting performance time series, the water consumption time series, and a current capacity of the water reservoir 150 in Step S150. In particular, the system 100 can calculate the operating power level time series over the prediction period based on the harvesting performance time series, the water consumption time series, and the current capacity of the water reservoir 150 by selecting an operating power level corresponding to each time interval in the harvesting performance time series such that the capacity of the water reservoir 150 is predicted to remain above a reserve

capacity for the duration of the prediction period and a total energy expenditure is predicted to be minimized over the prediction period based on a power level selection algorithm. Thus, by anticipating conditions and, therefore, water harvesting efficiency over the prediction period, the system 100 can select an operating power level schedule or time series that takes advantage of periods of increased water harvesting efficiency while avoiding periods of poor water harvesting performance.

[0127] The system 100 can calculate a time series of water deficits based on the current water capacity of the water reservoir 150, the water consumption time series, and the reserve water capacity. In one implementation, the system 100 can select a reserve capacity based on the location of the system 100, the species classification of the associated plant, the uncertainty or variability of regional meteorological conditions, and the average temperatures and average humidities in the region over the prediction period. Thus, the system 100 can inform a power level selection algorithm to select a time series of operating power levels that eliminate the time series of water deficits without exceeding the maximum capacity of the water reservoir 150.

[0128] In one implementation, the system 100 executes a power-level selection algorithm including a greedy algorithm. In this implementation, the system 100 can greedily select operating power levels for specific time intervals starting with the most efficient operating power level for a time interval in the prediction period and continuing to select operating power levels with descending efficiency until the model predicts zero water deficits over the prediction period. In this implementation, the system 100 can increase the weight of predicted harvesting efficiencies earlier in the prediction period based on the lower uncertainty in earlier predicted harvesting efficiency.

[0129] In another implementation, the system 100 executes a power-level selection model including a dynamic programming approach or a linear programming approach to select an operating level time series that is predicted to satisfy the constraints of remaining below the maximum water capacity of the water reservoir 150 while maintaining at least the reserve capacity of water in the water reservoir 150.

[0130] In yet another implementation, the system 100 executes a power-level selection algorithm including a genetic algorithm. In this implementation, the system 100 can: define a power level selection schedule as a sequence of operating power level selections, define a fitness function evaluating the energy consumption of the system 100 while satisfying the predicted time series of water deficits; and define genetic operations to iteratively mutate each power-level selection schedule until satisfying a convergence criteria.

[0131] In yet another implementation, the system 100 executes a power-level selection algorithm including a particle swarm optimization algorithm or particle filter algorithm. In this implementation, the system 100 can stochastically generate a set of power-level selection schedules and iteratively stochastically generate additional sets of power level selection schedules based on an objective function evaluated on a previous set of power level selection schedules.

[0132] In yet another implementation, the system 100 executes a power-level selection algorithm via a reinforcement learning agent. In this implementation, the system 100 can: define a state space representing a current time interval, the current water capacity of the reservoir, and a cumulative energy consumed; define an action space as a selecting operating power level for each time interval; define rewards based on energy consumption and satisfying the water deficit time series; and execute Q-learning or similar algorithms to train the agent during operation of the system 100.

[0133] However, the system 100 can execute any power-level selection algorithm that attempts to solve the optimization problem of minimizing power consumption while satisfying the constraints of the reserve capacity of the water reservoir 150, the maximum capacity of the water reservoir 150, and the predicted time series of water deficits.

[0134] In implementations including a power subsystem including a photovoltaic panel and battery 212, the system 100 can execute a power-level selection algorithm that satisfies additional constraints including a reserve capacity of the battery 212, a maximum capacity of the battery 212, and a time series of predicted energy deficits over the prediction period. More specifically, the system 100 can calculate the operating power level time series over the prediction period based on the harvesting performance time series, the water consumption time series, the current capacity of the water reservoir 150, the power production time series, and a current battery capacity. Thus, the system 100 can prevent itself from exceeding the amount of energy stored in the battery 212 while attempting to optimally harvest water from the atmosphere for the duration of the prediction period.

14.7. System Operation

[0135] Generally, upon calculating the operating power level time series (or the power level schedule), the system 100 can access a current operating power level in the operating level time series corresponding to the current time and operate the harvesting subsystem 140 and/or the convection subsystem 130 (in implementations including an active convection subsystem 130) according to the current operating power level. More specifically, the system 100 can operate the harvesting subsystem 140 and/or the convection subsystem 130 according to a current operating

power level corresponding to a current time in the operating power level time series. In instances where the current operating power level is zero, the system 100 does not operate the harvesting subsystem 140 and the convection subsystem 130. Thus, the system 100 determines the current operating power level that is part of an approximately optimal power level schedule for the prediction period.

[0136] In one implementation, the system 100 can, in response to accessing updated regional meteorological data, execute Steps S120, S130, S140, S150, S160, and, in some implementations, S170, to calculate an updated operating power level time series and, therefore, an updated current power level based on the updated regional meteorological data. Thus, the system 100 can periodically (e.g., every hour or at any rate that updated meteorological data is accessible) recalculate the power level schedule based on the most recent regional meteorological data.

[0137] the system 100s and methods described herein can be embodied and/or implemented at least in part as a machine configured to receive a computer-readable medium storing computer-readable instructions. The instructions can be executed by computer-executable components integrated with the application, applet, host, server, network, website, communication service, communication interface, hardware/firmware/software elements of a user computer or mobile device, wristband, smartphone, or any suitable combination thereof. Other systems and methods of the embodiment can be embodied and/or implemented at least in part as a machine configured to receive a computer-readable medium storing computer-readable instructions. The instructions can be executed by computer-executable components integrated by computer-executable components integrated with apparatuses and networks of the type described above. The computer-readable medium can be stored on any suitable computer readable media such as RAMs, ROMs, flash memory, EEPROMs, optical devices (CD or DVD), hard drives, floppy drives, or any suitable device. The computer-executable component can be a processor but any suitable dedicated hardware device can (alternatively or additionally) execute the instructions.

[0138] As a person skilled in the art will recognize from the previous detailed description and from the figures and claims, modifications and changes can be made to the embodiments of the invention without departing from the scope of this invention as defined in the following claims.

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CLAIMS

We Claim:

1. An atmospheric water harvesting system comprising:
 - a body defining:
 - a planter structure;
 - a base compartment; and
 - a plant receptacle;
 - a harvesting subsystem configured to extract water from ambient air;
 - a water reservoir arranged within the base compartment and configured to collect water extracted by the harvesting subsystem;
 - a water delivery structure configured to release water from the water reservoir into the plant receptacle;
 - a water dispensing subsystem configured to control water flow from the water reservoir to the water delivery structure;
 - a set of ambient sensors;
 - a set of delivery sensors; and
 - an electronic control subsystem.
2. The atmospheric water harvesting system of Claim 1, wherein:
 - the planter structure defines:
 - a perimeter shell around the plant receptacle;
 - an air inlet vent arranged on an upper surface of the perimeter shell;
 - an air outlet vent arranged on a bottom surface of the planter structure; and
 - an air conduit arranged within the perimeter shell and fluidically coupling the air inlet vent to the air outlet vent; and
 - a convection subsystem arranged within the base compartment and configured to cause ambient air to flow into the inlet vent, through the air conduit, and out of the outlet vent..
3. The atmospheric water harvesting system of Claim 1, wherein:
 - the planter structure defines:
 - a perimeter shell around the plant receptacle;
 - an air inlet vent arranged on a bottom surface of the planter structure;
 - an air outlet vent arranged on an upper surface of the perimeter shell; and
 - an air conduit arranged within the perimeter shell and fluidically coupling the air

inlet vent to the air outlet vent; and

- a convection structure arranged within the base compartment and configured to cause ambient air to flow into the inlet vent, through the air conduit, and out of the outlet vent.
4. An atmospheric water harvesting system comprising:
- a body defining:
 - a surface compartment;
 - a stake structure comprising a soil-penetrating extrusion extending downward from the surface compartment; and
 - a harvesting subsystem configured to extract water from ambient air;
 - a water reservoir arranged within the surface compartment and configured to collect water extracted by the harvesting subsystem;
 - a water delivery structure coupled to the soil-penetrating extrusion and configured to release water from the water reservoir;
 - a water dispensing subsystem configured to control water flow from the water reservoir to the water delivery structure;
 - a set of ambient sensors;
 - a set of delivery sensors; and
 - an electronic control subsystem.
5. An atmospheric water harvesting system associated with an associated plant comprising:
- a body defining a housing;
 - a harvesting subsystem configured to extract water from ambient air;
 - a water reservoir arranged within the housing and configured to collect water extracted by the harvesting subsystem;
 - a water delivery structure configured to release water from the water reservoir toward a root system of the associated plant;
 - a water dispensing subsystem configured to control water flow from the water reservoir to the water delivery structure;
 - a set of ambient sensors;
 - a set of delivery sensors; and
 - an electronic control subsystem configured to:
 - access regional meteorological data for a prediction period, the regional meteorological data comprising a regional temperature time series and a regional

- humidity time series;
- evaluate a local condition model to predict a local temperature time series and a local humidity time series over the prediction period based on the regional temperature time series and the regional humidity time series;
 - evaluate a harvesting performance model to predict a harvesting performance time series over the prediction period based on the local temperature time series and the local humidity time series;
 - evaluate a water consumption model to predict a water consumption time series for the associated plant over the prediction period based on the local temperature time series and the local humidity time series;
 - calculate an operating power level time series over the prediction period based on the harvesting performance time series, the water consumption time series, and a current capacity of the water reservoir; and
 - operate the harvesting subsystem according to a current operating power level corresponding to a current time in the operating power level time series.
6. The atmospheric water harvesting system of Claim 5, wherein the electronic control subsystem further comprises a remote server communicating with a processing device.
7. The atmospheric water harvesting system of Claim 5, wherein the electronic control subsystem is further configured to:
- access ambient data collected by the set of ambient sensors over a training period;
 - access regional meteorological data for the training period; and
 - train the local condition model based on the ambient data and the regional meteorological data.
8. The atmospheric water harvesting system of Claim 5, wherein the electronic control subsystem is further configured to:
- access delivery data collected by the set of delivery sensors over a training period;
 - access ambient data for the training period; and
 - train the water consumption model based on the delivery data and the ambient data for the training period.
9. The atmospheric water harvesting system of Claim 5, wherein the electronic control

subsystem is further configured to:

- evaluate the harvesting performance model to predict the harvesting performance time series over the prediction period based on the local temperature time series and the local humidity time series, the harvesting performance time series comprising a time series of performance functions predicting a water production rate and a harvesting efficiency over a range of operating power levels; and
- calculate the operating power level time series over the prediction period based on the harvesting performance time series, the water consumption time series, and the current capacity of the water reservoir by selecting an operating power level corresponding to each time interval in the harvesting performance time series such that the capacity of the water reservoir is predicted to remain above a reserve capacity for the duration of the prediction period and a total energy expenditure is predicted to be minimized over the prediction period based on a power level selection algorithm.

10. The atmospheric water harvesting system of Claim 5:

- wherein the body defines a planter structure;
- wherein the housing comprises a base compartment;
- further comprising a plant receptacle configured to hold the associated plant; and
- wherein the water delivery structure is configured to release water from the water reservoir into the plant receptacle.

11. The atmospheric water harvesting system of Claim 5, wherein:

- the housing comprises a surface compartment;
- the body defines a stake structure comprising a soil-penetrating extrusion extending downward from the surface compartment; and
- the water delivery structure is arranged within the soil-penetrating extrusion and configured to release water from the water reservoir toward the root system of the associated plant.

12. The atmospheric water harvesting system of Claim 5, further comprising a power subsystem comprising:

- a photovoltaic power source; and
- a battery.

13. The atmospheric water harvesting system of Claim 12, wherein the electronic control subsystem is further configured to:
- evaluate a power production and storage model to predict a power production time series over the prediction period; and
 - calculate the operating power level time series over the prediction period based on the harvesting performance time series, the water consumption time series, the current capacity of the water reservoir, the power production time series, and a current battery capacity.
14. The atmospheric water harvesting system of Claim 5, further comprising a power subsystem comprising a wireless power receiver.
15. The atmospheric water harvesting system of Claim 5, wherein the harvesting subsystem comprises a thermoelectric condenser configured to utilize air flowing through the air conduit as a heat sink.
16. The atmospheric water harvesting system of Claim 5, wherein the harvesting subsystem comprises a thermoelectric condenser comprising a cold plate contacting air flowing through the air conduit.
17. The atmospheric water harvesting system of Claim 5, wherein the harvesting subsystem comprises an electrohydrodynamic condenser.
18. The atmospheric water harvesting system of Claim 5, wherein the harvesting subsystem comprises a capture medium configured to capture water vapor from ambient air.
19. The atmospheric water harvesting system of Claim 5, wherein the set of ambient sensors comprises at least one of:
- an ambient temperature sensor;
 - an ambient humidity sensor;
 - an ambient pressure sensor;
 - an ambient light sensor; and

- a condenser temperature sensor.

20. The atmospheric water harvesting system of Claim 5, wherein the set of delivery sensors comprise at least one of:

- a pressure transducer arranged within the water reservoir and configured to detect the current capacity of the water reservoir; and
- a soil moisture sensor configured to detect a moisture content in soil surrounding a root system of the associated plant.