

SYSTEM, APPARATUS AND METHOD FOR LIQUID ATOMIZATION

5 TECHNICAL FIELD OF THE INVENTION

The invention relates to a system, apparatus and method for irrigation and increasing humidity in air.

BACKGROUND OF THE INVENTION

10 The following discussion of the background to the invention is intended to facilitate understanding of the present invention. However, it should be appreciated that the discussion is not an acknowledgment or admission that any of the material referred to was published, known or a part of the common general knowledge in any jurisdiction as at the priority date of the application.

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Moving air, such as wind, can function as a carrier of water across land and sea. When humid wind flows through a piece of land, soils absorb water from the humid wind (i.e., the direction of water absorption is from "air-to-soil").

20 In contrast, when dry wind such as foehn wind (valleys, hills), berg wind (South Africa) and plateau monsoon passes through a piece of land, it takes away water from soils (i.e., the direction of water absorption is from "soil-to-air"). Dry wind is one of the main problem behind desertification, degradation and salinization of lands, which causes serious harm to environment and
25 agriculture.

The conventional irrigation systems and methods in general require extensive delivery system from a water source to one or more destinations where irrigation takes place. A power pump, such as an electrical power plant
30 operates to pump water from water sources (e.g., underground water, river, stream, creep and well) to the destinations. However, such a delivery system is inconvenient, difficult or almost impossible to be applied to remote regions

where there is no established power plant available or where the soil conditions do not allow for such delivery systems to be constructed. In recent years, a new irrigation technology known as “micro-dialysis irrigation” has been developed, which might, to some extent, alleviate the environmental damages caused by dry wind. However, this irrigation method requires installation of micro-dialysis pipelines of about 40 cm to 60 cm (centimetres) below the soil-air interface to inject water into soils below the tillage layer. Further, such micro-dialysis irrigation method requires extensive construction work to build up the necessary infrastructure, and could negatively affect deep plough of the arable land. It is also difficult to control the volume of water in the micro-dialysis irrigation method – over-irrigation might happen to cause capillarity at the soil-air interface, which might consequently trigger and worsen land salinization.

Thus, there exists a need to develop an irrigation system that at least alleviates some of the technical problems identified above.

SUMMARY OF THE INVENTION

Throughout this document, unless otherwise indicated to the contrary, the terms “comprising”, “consisting of”, and the like, are to be construed as non-exhaustive, or in other words, as meaning “including, but not limited to”.

Throughout the specification, unless the context requires otherwise, the word “comprise” or variations such as “comprises” or “comprising”, will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

Throughout the specification, unless the context requires otherwise, the word “include” or variations such as “includes” or “including”, will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

Throughout the description, the term “windmill” refers to any device that converts the energy of wind into other forms of energy, including mechanical energy. Throughout the description, the term “pump” refers to any pump that
5 can be utilized to draw water out of a water source and directing the water to a specified destination.

Throughout the description, unless the context requires otherwise, the term “Absolute humidity” (abbreviated “H”) refers to the total mass of water vapour
10 present in a given volume of air. H does not take temperature into consideration. H in the atmosphere ranges from near zero to roughly 30 grams *per* cubic meter when the air is saturated at 30 °C.

Throughout the description, unless the context requires otherwise, the term
15 “Relative humidity” (abbreviated RH) refers to the ratio of the quantity of water vapour present in the atmosphere to the quantity that would saturate at a given temperature. RH is also the ratio of the partial pressure of water vapour to the equilibrium vapour pressure of water at a given temperature. Relative humidity depends on the temperature and the pressure of the system of
20 interest. It requires less water vapour to attain high relative humidity at low temperatures; more water vapour is required to attain high relative humidity in warm or hot air. The phrase “dry wind” refers to a bulk movement of air that has a low “relative humidity” (RH): the actual vapour pressure in the air is smaller than the saturation vapour pressure at a given temperature so that the
25 number of water molecules evaporating from a water-containing substance (e.g., soils, a pool of water) into the air is more than the number of water molecules condensing from the air back into the water-containing substance. Examples of the dry wind include, but not limited to, plateau monsoon, hill valley wind, river valley wind and foehn wind.

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Throughout the description, unless the context requires otherwise, the term “atomization” refers to compress a liquid (e.g., water) into fine droplets (e.g., in

aerosol or mist form) using pressure. The term atomization could include where droplets are nebulized.

Throughout the description, unless the context requires otherwise, the term
5 “sprinkler” (also known as spray head) refers to any device that emits liquids.

Throughout the description, unless the context requires otherwise, the term
“irrigation” refers to increasing the humidity of soils/land to foster plant growth
or environmental restoration.

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In accordance with an aspect of the present invention, there is a liquid
atomization system for irrigation, comprising: a liquid pump operable to pump
liquid from a liquid source; at least one conduit arranged to receive the liquid
from the liquid pump, wherein the at least one conduit includes a plurality of
15 atomizers operable to atomize the liquid received from the conduit; the system
further including at least one scaffold comprising at least one stand operable
to be affixed onto a surface and a plurality of horizontal bars, wherein the at
least one conduit is supported by the plurality of horizontal bars; wherein the
at least one scaffold is installed at a land location to enable the atomized
20 liquid that is released by the plurality of atomizers to be carried by wind
passing the plurality of horizontal bars.

Preferably, two adjacent horizontal bars of the plurality of parallel horizontal
bars are configured to be spaced apart from each other at a first
25 predetermined distance.

Preferably, the first predetermined distance is calculated based on at least
one parameter of the wind: barometric pressure P , water vapour pressure p ,
saturated water vapour pressure p_s , height, temperature t , absolute humidity
30 H , relative humidity ϕ , dew point t_d , speed, direction and shear.

Preferably, the speed ranges from 0.8 m/s to 8 m/s, and the first predetermined distance ranges from 30 cm to 45 cm.

5 Preferably, the first predetermined distance can be dynamically adjusted via a programmable logic controller arranged with an actuator to move the plurality of parallel horizontal bars.

Preferably, two adjacent atomizers of the plurality of atomizers are configured to be spaced apart from each other at a second predetermined distance.

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Preferably, the second predetermined distance is calculated based on at least one parameter of the wind: barometric pressure P , water vapour pressure p , saturated water vapour pressure p_s , height, temperature t , absolute humidity H , relative humidity ϕ , dew point t_d , speed, direction and shear.

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Preferably, the at least one stand is fixed with an angle Θ to the surface, and the angle Θ is smaller than 90 degree.

20 Preferably, two adjacent atomizers of the plurality of atomizer are configured to spray the atomized liquid in opposite directions from the scaffold 106.

25 Preferably, a number of the at least one conduit to be placed on the scaffold is determined based on at least one parameter of the wind: barometric pressure P , water vapour pressure p , saturated water vapour pressure p_s , height, temperature t , absolute humidity H , relative humidity ϕ , dew point t_d , speed, direction and shear.

30 Preferably, the at least one conduit is placed at least 12 meters above the surface.

Preferably, the liquid pump is powered by an energy source.

Preferably, the energy source is a wind-powered generator.

Preferably, the scaffold and the wind-powered generator are integrated into a single apparatus.

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Preferably, the wind-powered generator comprises a wind tower comprising a tower-top structure, and the scaffold is placed on the tower-top structure.

Preferably, the liquid pump is a reciprocating pump.

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Preferably, the liquid pump is operable by either a mechanical force or an electrical force or both.

Preferably, the atomizer comprises at least one sprinkler.

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Preferably, the at least one sprinkler comprises one or more nozzles.

Preferably, the one or more nozzles comprise at least one air atomizing nozzle, at least one fine spray nozzle, at least one hollow cone nozzle, at least one flat fan nozzle, at least one full cone nozzle, at least one hydraulic fine spray, or a combination thereof.

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Preferably, the at least one air atomizing nozzle is selected from the group comprising flat spray nozzle, round spray nozzle, wide-angle spray nozzle and external mix nozzle.

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Preferably, the at least one sprinkler is operable to atomize the liquid into liquid droplets that have a diameter ranging from 10 μm to 120 μm .

30 Preferably, the liquid is water, and the liquid source is a water source.

Preferably, the at least one conduit is a pipe made of PVC (PolyVinyl Chloride), CPVC (Chlorinated Polyvinyl Chloride), PEX (Cross-linked polyethylene), copper, carbon steel or any combination thereof.

- 5 Preferably, the diameter of the at least one conduit ranges from 8 mm to 50 mm.

Preferably, the liquid moves inside the at least one conduit at a speed ranging from 1.8 m/s to 8 m/s.

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Preferably, a plurality of the at least one conduit is assembled using a plurality of quick connectors.

Preferably, one or more additives are added in the liquid source.

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Preferably, the one or more additives comprise at least one compressed gas and/or at least one surfactant.

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Preferably, the surfactant is selected from the group comprising stearate, sodium dodecyl benzene sulphonate (SDBS) and triethanolamine (TEA).

Preferably, the surfactant is added into the liquid source at a proportion by weight of 10 to 320 ppmw (parts per million by weight).

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Preferably, a wind detection module operable to detect at least one parameter of the wind, and a control module configured to receive the at least one parameter from the wind detection module.

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Preferably, the control module is configured to control the operation speed of the liquid pump.

Preferably, the at least one conduit comprises one or more valves.

Preferably, each of the plurality of atomizers comprises one or more valves.

5 In accordance with another aspect of the invention, there is a method for installing a liquid atomization system for irrigation at a location where there is wind flowing through, comprising the steps of: (a) installing at least one energy source, at least one liquid pump and at least one scaffold comprising at least one stand operable to be affixed onto a surface and a plurality of horizontal bars; (b) connecting the energy source to power the liquid pump
10 that is configured to pump liquid from a liquid source; (c) connecting the liquid pump to at least one conduit comprising a plurality of atomization means; (d) placing the at least one conduit on the plurality of horizontal bars.

Preferably, the method further comprises a step of separating two adjacent
15 horizontal bars from the plurality of horizontal bars from each other at a first predetermined distance.

Preferably, the method further comprises a step of separating two adjacent atomization means of the plurality of atomization means from each other at a
20 second predetermined distance.

Preferably, the method further comprises a step of measuring at least one parameter of the wind for determining the location: barometric pressure P , water vapour pressure p , saturated water vapour pressure p_s , height,
25 temperature t , absolute humidity H , relative humidity ϕ , dew point t_d , speed, direction and shear.

Preferably, the method further comprises a step of measuring at least one parameter of the wind for determining the first predetermined distance:
30 barometric pressure P , water vapour pressure p , saturated water vapour pressure p_s , height, temperature t , absolute humidity H , relative humidity ϕ , dew point t_d , speed, direction and shear.

Preferably, the method further comprises a step of arranging the first predetermined distance to range from 30 cm to 45 cm for the speed of 0.8 m/s to 8 m/s.

- 5 Preferably, the method further comprises a step of measuring at least one parameter of the wind for determining the second predetermined distance: barometric pressure P , water vapour pressure p , saturated water vapour pressure p_s , height, temperature t , absolute humidity H , relative humidity ϕ , dew point t_d , speed, direction and shear.

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Preferably, the method further comprises a step of calculating the absolute humidity H from the water vapour pressure p and the barometric pressure P based on a formula expressed as:

$$H = 0.622 \frac{p}{P - p}$$

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Preferably, the method further comprises a step of calculating the relative humidity ϕ from the water vapour pressure p and the saturated water vapour pressure p_s based on a formula expressed as:

$$\phi = \frac{p}{p_s} * 100\%$$

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Preferably, the method further comprises a step of calculating the saturated water vapour pressure p_s from the temperature t based on a formula expressed as:

$$P_s = \frac{2}{15} \exp \left(18.5916 - \frac{3991.11}{t - 233.94} \right)$$

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Preferably, the method further comprises a step of calculating the relative humidity ϕ from the absolute humidity H , the water vapour pressure p and the saturated water vapour pressure p_s based on a formula expressed as:

$$\phi = \frac{HP}{(H+0.622)p_s}$$

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Preferably, the method further comprises a step of calculating the dew point t_d from the water vapour pressure p based on a formula expressed as:

$$t_d = \frac{3991.11}{16.58 - \ln p} - 233.84$$

- 10 Preferably, the method further comprises a step of constructing a downward stair-style impoundment in a streambed as the liquid source.

Preferably, the method further comprises a step of creating a layer of artificial permafrost on a land damaged by the wind.

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Preferably, the method further comprises a step of growing a plurality of plants on a land damaged by the wind.

- 20 Other aspects of the invention will become apparent to those of ordinary skill in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

- 25 The present invention provides a simplified irrigation system over the prior arts that in general require complex infrastructure and extensive power input (e.g., micro-dialysis irrigation method). The present invention is operable to operate a liquid pump to pump liquid (e.g., water) into conduits (e.g., pipes) comprising a plurality of atomizers operable to atomize the liquid, wherein the conduits are placed on a scaffold installed at a land location where there is wind

flowing through. Thus, when wind flows through the liquid atomizer system, the wind becomes moisturized and can scatter liquid (e.g., water) droplets across soils that have been damaged by the dry wind. The present method therefore might alleviate the environmental damages (e.g., desertification, degradation and salinization of land) caused by the dry wind, and even facilitate the restoration and recovery of the damaged land. Furthermore, the scaffold is configured to have a plurality of horizontal bars applied to hold the conduits, retaining sufficient distances between the adjacent atomizers. Thus, the atomized liquids spraying from adjacent atomizers will not aggregate into large water droplets too fast so that the water droplets can be carried away by the moving wind over a long distance.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1a is an illustrative view of an embodiment of the liquid atomization system.

Figure 1b is an illustrative partial front view of an embodiment of the scaffold.

Figure 2 is a photograph of an embodiment of the wind-powered liquid atomization system installed in a field.

Figure 3 includes a front view (right) and a side view (left) of an embodiment of the wind-powered liquid atomization system.

Figure 4 includes pictures of various types of quick connectors that can be used for the liquid atomization system.

Figure 5 is an illustrative top perspective view of an embodiment of the liquid atomization system comprising a plurality of scaffolds.

Figure 6a is an illustrative side view of various types of configurations that install the liquid atomization means onto the scaffold.

Figure 6b is an illustrative side view of an embodiment of the scaffold.

Figure 6c is an illustrative side view of an embodiment of the scaffold.

Figure 6d is an illustrative front view of an embodiment of the scaffold.

Figure 7 is an illustrative front view of an embodiment of the liquid atomization system.

Figure 8 is an illustrative flowchart of the steps that might be used in implementing the liquid atomization system to restore and recover a damaged
5 land.

Figure 9 is an illustrative view of an embodiment of the control system for the liquid atomization system.

Other arrangements of the invention are possible and, consequently, the
10 accompanying drawings are not to be understood as superseding the generality of the preceding description of the invention.

DETAILED DESCRIPTION

15 Particular embodiments of the present invention will now be described with reference to the accompany drawings. The terminology used herein is for the purpose of describing particular embodiments only and is not intended to limit the scope of the present invention. Additionally, unless defined otherwise, all technical and scientific terms used herein have the same meanings as
20 commonly understood by one of ordinary skill in the art to which the present invention belongs. Where possible, the same reference numerals are used throughout the figures for clarity and consistency.

Apparatus and System

25 In accordance with an aspect of the invention there is a liquid atomization system that produces small droplets or an aerosol or a mist from a liquid to introduce such droplets of liquid into air. The liquid may be water and is introduced into air for the purpose of increasing the relative humidity of the same.

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In one embodiment of the invention as illustrated in Figure.1, the liquid atomization system 100 comprises an energy source 101, a pump 102, one or more conduits 104, one or more atomizer 105 (e.g., sprinklers), and a scaffold

106. The energy source 101 is connected (110) to drive the pump 102. The pump 102 is connected (120) into a liquid source (103) (e.g., water or other types of liquid). The pump 102 is connected to the one or more conduits 104 (e.g., pipe) that are placed on the scaffold 106. Each pipe has multiple
5 atomizers 105.

The energy source 101 is operable to utilize any type of energy including, but not limited to, solar power, wind power, hydropower/water power (e.g., energy of falling water or fast running water), electrical power, mechanical power and
10 any combination thereof.

In a further embodiment of the invention, the energy source is a wind-powered generator. In a further embodiment, the wind-powered generator is a windmill or a wind turbine. When wind blows through the liquid atomization system
15 100, the windmill 101 captures wind energy and converts the wind energy into a mechanical energy (or an electrical energy) to operate the pump 102 to draw water from the water source 103 into the conduits 104 held on the scaffold 106. When the water flows through the conduits 104, the atomizer 105 ejects water from the conduits to produce water droplets fine enough to
20 be carried away by the blowing wind. In a further embodiment of the invention, the atomizing mean 105 is a sprinkler.

In a further embodiment, the atomized water droplets are in non-spherical shape (or nearly spherical shape), having a diameter from 10 to 120 μm
25 (micrometre). In a preferred embodiment, the atomized non-spherical water droplets have a diameter ranging from 10 to 20 μm . In a further embodiment, the non-spherical droplet is achieved by adding pressurized gas 109 into the liquid source 103, wherein the pressurized gas 109 will cause the water to burst into droplets that have irregular shapes (e.g., non-spherical shape).
30 There are technical advantages in generating droplets that have non-spherical shapes described as follows.

When a droplet is being moved forward by the blowing wind, the droplet will form an area of air-liquid mixture at its back. This area of air-liquid mixture is referred to as "tail area" throughout this specification. The tail area of a non-spherical (or nearly spherical) droplet is in general more than 2.5 times longer than that of a spherical droplet. The air-liquid ratio in the tail area of a non-spherical (or nearly spherical) droplet is more than 3.2 times higher than that of a spherical droplet – in another word, there will be more air in the tail area of a non-spherical (or nearly spherical droplet) and the liquid is being dispersed in a larger volume of air, accordingly improving the efficiency in mixing liquid and water and facilitating the absorption of liquid by the moving wind. The wind can therefore carry the liquid away for a longer distance, and irrigate a larger geographical area.

In a further embodiment, after the wind passes through the liquid atomization system 100, the flowing liquid-air mixture has a density from 0.009 to 0.05 g/cm³.

In a further embodiment of the invention that utilizes a windmill as the energy source 101, the windmill 101 comprises a plurality of rotary blades. When the wind blows through the windmill 101, the rotation of the blades turns a wheel that is attached to a shaft. The shaft has pinion gears at the other end inside a gearbox. The gears are connected to a pump rod of the liquid pump 102 to move the pump rod up and down. When the pump rod is moved, liquid (e.g., water) is pulled out from the liquid source 103 into the conduits 104. In some alternative embodiments of the invention, the pump 102 is an electrical pump driven by electrical power. In a further embodiment of the invention, the windmill 101 is equipped with an energy converter to first convert the wind energy into an electrical energy and then utilizes the electrical energy to operate the pump to draw liquid (e.g., water) from the liquid source 103.

In a further embodiment of the invention, a plurality of energy sources 101 is utilized to operate the pump 102. In a further embodiment of the invention, the plurality of energy sources 101 comprises devices and apparatuses utilizing

different types of energy including, but not limited to, solar power (e.g., solar panel), wind power (e.g., wind turbine), water power (e.g., waterwheel) or electrical power (e.g., from an electrical grid).

5 In a further embodiment of the invention, the pump 102 is a reciprocating pump. Examples of the reciprocating pump includes, but not limited to, the piston pump, plunger pump, diaphragm pump as well as other types of positive-displacement pumps. In a further embodiment of the invention, there is a chamber in the reciprocating pump that traps the liquid (water or other
10 types of liquid). The chamber might take the form of a stationary cylinder that contains a piston or plunger. In a further embodiment, it is preferable to lower the chamber below the surface of the liquid source 103 as much as possible. In a further embodiment of the invention, the reciprocating pump is able to produce a pressure up to 40Mpa (megapascal) to raise water into the liquid
15 conduits 104 installed above the ground. In a further embodiment, the reciprocating pump is able to deliver water into conduits that are placed more than 400 meters above the ground.

In a further embodiment of the invention, the pump 102 is driven by
20 mechanical force. The windmill 101, after harvesting wind energy, directly converts the wind energy into mechanical energy to operate the mechanical pump. In some alternative embodiments of the invention, the pump 102 is an electrical pump driven by electrical power. The windmill 101, after capturing the wind energy, converts the wind energy into electrical power, and utilizes
25 the electrical power to operate the pump 102.

The liquid source 103 is preferably free of debris, sands, gravels and stones, as these impurities might affect the durability and stability of the liquid atomization system 100. In a further embodiment of the invention, the
30 connecting pipe 120 between the liquid source 103 and the pump 102 is equipped with a filtering device to prevent debris, sands, gravels and stones from entering into the liquid atomization system 100. Removing debris and

contaminants from the liquid being pumped into the conduits 104 could prevent clogging of or damage to the conduits 104 and the sprinklers 105.

5 In a further embodiment of the invention, one or more additives are added into the liquid source 103 to enhance the efficiency of liquid atomization. One type of additive is pressurized gas (also known as compressed gas). Another type of additive is surfactant that can lower the surface tension (or interfacial tension) between liquid and air, as decreases in surface tension decrease droplet size. Examples of surfactant includes, but not limited to, stearate, 10 sodium dodecyl benzene sulphonate (SDBS), triethanolamine (TEA) and other similar compounds. In a further embodiment of the invention, the surfactant is added into the liquid source at a proportion by weight of 10 – 320 ppmw (parts per million by weight). In a further embodiment of the invention, different types of additives are added into the liquid source 103 together to 15 enhance the efficiency of liquid atomization.

In a further embodiment of the invention, the conduits (e.g., pipes) 104 are held up on a large scaffold 106 installed at a location where dry wind often blows through. In a further embodiment, the pipes are made of carbon steel. 20 In a further embodiment, the pipes are made of a soft material such as plastic. In a further embodiment, the pipe is PVC (PolyVinyl Chloride) pipe, CPVC (Chlorinated Polyvinyl Chloride) pipe, PEX (Cross-linked polyethylene) pipe, copper pipe or galvanized pipe.

25 In a further embodiment of the invention, according to the size of the area to be irrigated and the conditions of the wind (e.g., wind speed), the diameter of the conduit 104 is configured to preferably range from about 8 millimetres (mm) to 50 mm. The moving speed of the liquid-air mixture inside the conduit 104 is controlled to preferably range from about 1.8 m/s to about 8 m/s.

30 In a further embodiment of the invention, the scaffold 106 comprises one or more stands 106a that are vertical to the land surface, as well as one or more horizontal bars 106b that are parallel to the land surface. In a further

embodiment, the conduits 104 are installed on the one or more horizontal bars 106b that are parallel to the land surface. The lateral length and the height of the horizontal bars 106b can be adjusted to maximize the absorption of the water droplets by the moving wind (e.g., depending on the wind speed). In a further embodiment, the height of the horizontal bars 106b is at least 12 meters above the land surface. The scaffold 106 can be made of any material that has sufficient strength to support the weight of the conduits 104 (e.g., pipes) and the scaffold 106.

10 In a further embodiment of the invention, a first predetermined distance 108 between two adjacent conduits 104 can be adjusted according to the wind speed and the area size of the hill slope (the dry wind flows down the slope) to ensure that the wind passing through can be substantially moisturized to have a relative humidity higher than that of the soils. In a further embodiment, the first predetermined distance 108 between two adjacent conduits 104 can be adjusted to ensure that the water droplets from the nearby sprinklers 105 will not aggregate into large water droplets too fast so that the water droplets can be carried away by the moving wind over a long distance. Two conduits 104 are considered "adjacent" conduits if one conduit 104 is located immediately next to the other conduit 104.

In a further embodiment of the invention, when the wind speed ranges from about 0.8 m/s to about 8 m/s, the first predetermined distance 108 is arranged to range from about 30 cm to about 45 cm.

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In a further embodiment, adjusting the first predetermined distance between the adjacent conduits 104 is achieved by utilizing a programmable logic controller (PLC) arranged with an actuator to dynamically move the horizontal bars 106b of the scaffold 106 according to one or more parameters of the wind such as wind speed and wind direction. In a further embodiment of the invention, an anemometer is installed on the scaffold 106 to measure wind speed in real-time and is arranged to transmit the measurement result to the PLC which is operable to calculate the optimal distance between the adjacent

conduits 104 so that water droplets will not aggregate into large water drops too fast. In a further embodiment of the invention, the distance between the adjacent conduits 104 near the top of the scaffold 106 is arranged to be smaller than that between the adjacent conduits 104 near the bottom of the scaffold 106.

In a further embodiment of the invention, the lowest conduit 104 is located at least 12 meters above the ground so that the atomized water droplet can be more stably absorbed and carried away by the moving wind.

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In a further embodiment of the invention, a second predetermined distance 107 between two adjacent sprinklers 105 can be adjusted according to at least one parameter of the dry wind, such as barometric pressure P , water vapour pressure p , saturated water vapour pressure p_s , height, temperature t , absolute humidity H , relative humidity ϕ , dew point t_d , speed, direction and shear. In a further embodiment, the second predetermined distance 107 between two adjacent sprinklers 105 can be adjusted to ensure that the water droplets will not aggregate into large water droplets and precipitate too fast so that the water droplets can be carried away by the moving wind over a long distance. Two sprinklers 105 are considered "adjacent sprinklers" if one sprinkler is located adjacent and close to the other sprinkler. For example, in Figure 1b, sprinklers 105a and 105b are adjacent sprinklers; sprinklers 105d and 105c are adjacent sprinklers; sprinklers 105b and 105c are adjacent sprinklers; sprinklers 105a and 105d are adjacent sprinklers.

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In a further embodiment, the conduits (e.g., pipes) 104 are assembled together using a plurality of quick connectors (or known as "quick connect fitting", "quick disconnect" or "quick release coupling"). The quick connectors refer to couplings used to provide a fast, make-or-break connection of fluid transfer lines (fluid conduits). Operated by hand, quick connectors can replace threaded or flanged connections, which require wrenches. The quick connectors are particularly suited for the installation of the present invention

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because the locations of the liquid atomization system 100 are often in wilderness where there are limited resources and infrastructures to support sophisticated construction work. Using quick connectors might simplify the construction methods. Also, as the scaffold 106 is of significant height, constructing the scaffold might require staffs and engineers to work high above the ground. Using quick connectors for the scaffold 106 and the liquid conduit 104 could simplify the construction methods, and accordingly reduce the risks for the construction staffs/engineers. Examples of quick connectors suitable for the present invention are illustrated in Figure 4, including a three-head quick connector 410, a L shape two-head quick connector 411, two-head quick connectors (420, 421 and 422), a quick connector suitable for handling high-pressure fluid 430, a two-head quick connector suitable for handling medium-pressure liquid 440 and a three-head quick connector suitable for handling medium-pressure fluid 441.

In a further embodiment of the invention, a single liquid atomization system 100 is able to scatter atomized water droplets over an area of roughly 40 hm². In a further embodiment of the invention, as illustrated in Figure.5, where a large piece of land needs to be covered and a large volume of wind needs to be moisturized, a plurality of the liquid atomization systems 100 is installed to increase the overall geographical coverage. In a further embodiment of the invention, a plurality of the liquid atomization systems 100 are installed in a horizontal row (in direction X of Figure 5) to increase the liquid atomization system 100 overall geographical coverage so that the atomized water droplets can be scattered across a larger geographical area. In some embodiments of the invention, a group of liquid atomization systems 100 is installed together back-to-back in a column (in direction Y of Figure 5) so that the flowing dry wind will pass through multiple liquid atomization systems 100 to get moisturized. In one embodiment of the invention, as illustrated in Figure 5, a plurality of scaffolds is installed and arranged into multiple rows and columns (e.g., three (3) rows x two (2) columns) to moisturize a large volume of wind 503. A Y distance 501 between two adjacent scaffolds 106 installed back-to-

back in the direction Y is predetermined to ensure that water droplets from adjacent scaffolds 106 do not aggregate into large water drops too fast. A X distance 502 between two adjacent scaffolds installed in the direction X is predetermined to ensure that there is no gap between the liquid atomization systems 100 for dry wind to flow through without being moisturized. In Figure 5, two scaffolds are considered adjacent scaffolds if two scaffolds are installed adjacent each other in either the direction X or the direction Y.

In some further embodiments of the invention, the stand 106a of the scaffold 106 is installed with an angle Θ to land surface 608, wherein the angle Θ is smaller than 90 degree. As illustrated in Figure 6a, having the stand 106 installed with an angle Θ to the land surface 608 spatially moves two adjacent sprinklers further apart in a horizontal direction, which may prevent liquid droplets 606 spraying from the two adjacent sprinklers 105 from aggregating into large liquid drops too fast. Figure 6b illustrates a plurality of the scaffolds 106 that are installed with an angle Θ to land surface 608, wherein the angle Θ is smaller than 90 degree.

In some alternative embodiments of the invention, the adjacent sprinklers 105 are installed on the two opposite sides of the scaffold 106 so that the liquid droplets from the adjacent sprinklers 105 are being sprayed out in opposite directions. Such a configuration might prevent liquid droplets from the adjacent sprinklers 105 from aggregating into large liquid drops and precipitating too fast. Figure 6c illustrates (a side view) a plurality of the scaffolds 106 that have adjacent sprinklers 105 installed on the two opposite sides of the scaffold 106. Figure 6d illustrates (a front view) a scaffold 106 that has adjacent sprinklers installed on the two opposite sides of the scaffold 106. Sprinklers 105b labelled in black colour position their nozzles (or spray heads) towards the back side of the scaffold 106, and Sprinklers 105a labelled in white colour position their nozzles (or spray heads) towards the front side of the scaffold 106. In operation, the sprinklers 105b in black and the sprinklers 105a in white spray liquid droplets towards opposite directions.

In some further embodiments wherein the liquid atomization system 100 is powered by wind energy, the liquid atomization system 100 comprises a wind direction control unit (e.g., rudder). The wind direction control unit is operable to detect changes in the wind direction, and accordingly to adjust the orientations of the rotary blades of the windmill 101 to maximize the capture of wind energy so that adequate liquid (e.g., water) can be pumped into the liquid atomization systems 100 to moisturize the moving wind. In a further embodiment, the direction control unit is operable to dynamically adjust the orientations of the scaffolds 106 so that the wind direction 503 is substantially vertical to the direction X (Figure 5). This ensures that the moving wind will pass through the liquid atomization systems 100 to get moisturized.

In a further embodiment of the invention, some conduits 104 comprise one or more valves 701 operable to regulate liquid flow inside the conduits 104. In a further embodiment of the invention, the valve 701 is a relief valve that is designed or set to open at a predetermined pressure level. There are various technical advantages of installing relief valves in some of the conduits 104. For example, for a liquid atomisation system 100 powered by a windmill 101, if the dry wind passing through is having a high wind speed, and therefore can carry liquid droplets away very fast, liquid droplets spraying from adjacent are less likely to aggregate into large liquid drops. In such a circumstance, the pump 102 is operable to draw more liquid into conduits 104 and accordingly to impose high pressure on the flowing liquid inside the conduits 104. The relief valves 701 will therefore open under such high pressure, allowing more sprinklers 105 to spray fine liquid droplets to moisturize the strong wind.

In a further embodiment of the invention wherein the energy source 101 is a windmill. A strong wind passing through the liquid atomisation system will enable the windmill 101 to generate more power to pump more liquid into the conduits 104. Thus, the pressure of the flowing liquid inside the conduits 104 is expected to increase automatically as the wind speed increases. The relief

valves will therefore automatically open to allow more sprinklers 105 to spray fine droplets. As the wind speed is high, the problem of droplet aggregation is unlikely to occur even when there are more sprinklers in operation to spray droplets. When a gentle wind passes through the liquid atomisation system,
5 the windmill 101 will generate less power and therefore will pump less liquid into the conduits 104. The relief valves will then stay closed, and decrease the number of sprinklers in operation. This might mitigate the technical problem of droplet aggregation when the wind speed is relatively low.

10 Preferably, more than 80% of the atomized water droplets stay in the wind for at least 20 minutes. If the wind speed is of Beaufort scale 4 and above, the wind can scatter the water droplets as far as 5,000 meters.

The sprinklers 105 installed on the conduits 104 can take various forms and
15 utilize various mechanisms, such as impact sprinkler, rain-gun, oscillating sprinkler, drip sprinkler, rotator style pivot applicator sprinkler. In a further embodiment of the invention, when water flows through the pipes, it exerts shear stress on the inner wall of the pipes 104. The shear stress then forces the flowing water to eject out of the pipes 104 through the sprinklers installed
20 along the pipes 104. The sprinklers then atomize the ejecting water into sprays/droplets fine enough to be absorbed and carried away by the wind. In a further embodiment of the invention, the sprinklers 105 utilize an aerosol compressor to vaporize droplets (i.e., atomizer). In a further embodiment of the invention, the sprinklers 105 use high-frequency sound wave (i.e.,
25 ultrasonic) to vaporize droplets. The wind's absorption of the water droplets might be facilitated by the water-density (humidity) difference between the water atomization zone and the wind.

In a further embodiment of the invention, each sprinkler 105 comprises one or
30 more nozzles. Examples of the nozzles include, but not limited to, air atomizing nozzle, fine spray nozzle, hollow cone nozzle, flat fan nozzle, full cone nozzle, and other types of hydraulic fine spray. In some preferred embodiments of the present invention, an air atomizing nozzle is used to

generate fine droplets, wherein compressed air (as the additive 109) is added into the liquid 103 to improve the efficiency of liquid atomization. Adding compressed air into the liquid 103 can also result in non-spherical droplets, which, in comparison to spherical droplets, have a larger and longer tail area in which the liquid is being dispersed in a larger volume of air.

Examples of the air atomizing nozzle includes, but not limited to, flat spray nozzle, round spray nozzle, wide-angle spray nozzle and external mix nozzle.

As appreciated by a person skilled in the art, the design and arrangement of the liquid atomization system 100 can be adjusted to optimize the effectiveness of the liquid atomization system 100 in alleviating the environmental damages of dry wind.

Installation Location

In order to minimize the environmental damages caused by dry wind such as plateau monsoon, hill valley wind, river valley wind, berg wind and foehn wind, the liquid atomization system 100 is preferably installed at a location where such dry wind regularly passes through and has been causing (or has the potential to cause) desertification, degradation and salinization of land.

Liquid source

In a further embodiment of the invention, the liquid atomization system 100 is installed at a location close to a liquid source that is a water source 103. Examples of the water source include, but not limited to, river, natural or artificial water reservoir, groundwater, stream, creek, well, lake, pond and sea. In some preferred embodiments of the invention, the water source is relatively free of debris, sands, gravels and stones.

Figure.2 and Figure.3 illustrate embodiments of a wind-powered liquid atomization system 200 installed in field. In Figure.2, the windmill 201 is installed on a piece of lowland 240 that is partially surrounded by

hills/mountains and is facing a river 203. Wind blowing down the hills might become foehn wind, which is dry and warm. Without proper intervention, such foehn wind, because of its low relative humidity and high relative temperature, could induce evaporation and thereby absorb water from at least the soil surface of the lowland 240, overtime causing desertification, degradation and salinization of the lowland 240. After the wind-powered liquid atomization system 200 is installed on the lowland 240, the foehn wind would trigger the blades of the windmill 201 to rotate. The rotation of the blades then harvests the wind energy and converts it into a suitable form of energy (e.g., mechanical energy, electrical energy) that can be utilize to operate a water pump (not shown in Figure.2). The water pump then draws water from the nearby water source 203 (e.g., the nearby river and/or the underground water), and transfers the obtained water into a plurality of pipes 204 placed on a scaffold 206. As illustrated in Figure.2, the plurality of pipes 204 and the scaffold 206 are installed behind the windmill to face to the wind blowing down from the surrounding hills. Each pipe 204 is equipped with a plurality of sprinklers (not shown in Figure.2). When water is pumped into the pipes, the flow of the water inside the pipes generates shear force, which then pushes some of the flowing water out of the pipes through the sprinklers. The sprinklers then atomize the ejecting water into fine water sprays/droplets that will be absorbed and carried away by the dry and warm foehn wind. After passing through the pipes, the relative humidity of the originally dry and warm foehn wind increases significantly. The humidified wind does not just stop absorbing water from soils, but can also function as a carrier to spread water (e.g., in aerosol form or mist form) over a large geographical area, providing an ecofriendly irrigation method to supply water to soils and plants of the surrounding areas. In the long run, the wind-powered liquid atomization system 200 could at least alleviate the environmental damages caused by the dry wind, and accordingly help restore and recover the ecosystem of the lowland 240.

In a further embodiment of the invention, if the water source for the wind-powered liquid atomization system 200 is a river, stream or creek, a downward “stair-style” impoundment can be created on the river/stream/creek bed to facilitate water supply to the wind-powered liquid atomization system 200 by reducing impurities and contaminants (e.g., sands, debris, gravels, stones, rocks) in the water source 203. In a further embodiment of the invention, the “stair-style” impoundment is constructed according to the natural slope/natural drop of the watercourse. Preferably, the construction of the “stair-style” impoundment should not change the cross-sectional area of the watercourse, nor affect the flood runoff of the water course. Such a “stair-style” impoundment can function to decrease the water flow rate, facilitating the settlement/precipitation of gravels, sands, rocks and stones. When pumping water into the water inlet of the wind-powered liquid atomization system 200, the “stair-style” impoundment might prevent such gravels, sands, rocks and stones from getting into the wind-powered liquid atomization system 200. This could alleviate the damaging effects of gravels, sands, rocks and stones on the components of the wind-powered liquid atomization system 200, improving the durability and stability of the system.

As illustrated in Figure.3, in a further embodiment of the invention, if the water source for the wind-powered liquid atomization system 200 is a river valley 203 that has a curved corner, the water inlet 220 of the pump 202 of the wind-powered atomization system 200 will be placed at the upstream of the curved corner. At the curved corner of a river, water will start rotary motion, which will facilitate precipitation of debris such as rocks, stones and gravels, and accordingly separate large impurities and contaminants from the water. Placing the water inlet 220 of the pump 202 at the upstream of the curved corner may prevent large impurities from entering into the wind-powered liquid atomization system 200.

As illustrated in Figure.3, in a further embodiment of the invention, the scaffold 206 and the windmill 201 can be integrated into a single apparatus, wherein the sprinklers 205 and the scaffold 206 are positioned above the blades of the

windmill 201. In a further embodiment of the invention, the windmill comprises a wind tower that comprises a tower-top structure 208. The scaffold 206 is then placed on the tower-top structure 208. The tower-top structure 208 is configured to connect the scaffold 206 to the tower of the windmill 201. Both
5 the front view 200a and the side view 200b of the wind-powered liquid atomization system are illustrated in Figure.3. Such an integrated design of the wind-powered liquid atomization system 200 is compact in size, particularly suitable for locations limited by space (e.g., hill valley, mountainous area).

Inflection Zone

The installation location of the liquid atomization system 100 can be adjusted in order to optimize the effectiveness of the liquid atomization system 200 in alleviating the environmental damages of dry wind. For example, in a further
15 embodiment of the invention, prior to the installation, relevant field tests have been carried out to measure parameters of the airflow (e.g., the dry wind) such as its barometric pressure, height, temperature, absolute humidity, relative humidity, dew point, speed, direction and shear. Based on the measurements made, an “inflection zone” wherein the direction of water
20 absorption changes from “air-to-soil” to “soil-to-air” can be determined and accordingly used as the installation site for the liquid atomization system 200.

A method to determine the “inflection zone” is disclosed in the present invention. During the movement of wind, as pressure, speed and temperature
25 of the moving wind change, the direction of liquid (e.g., water) absorption at the air-soil interface changes accordingly. When wind moves through a piece of land, the direction of water adsorption at the air-soil interface could be determined by various factors (e.g., air pressure, temperature, wind speed, wind direction, wind shear) that influence the absolute humidity, relative
30 humidity and dew point of the moving wind.

When wind moves, according to the law of conservation of energy, the total energy of the wind remains constant (without considering the resistance to flow) and can be expressed in the formula below:

$$\frac{u^2}{2} + \frac{P}{\rho} + gZ = Const$$

5

wherein, the definitions and units of the symbols in the above formula are:

P fluid pressure (unit: Pa)

Z distance (change in vertical height during fluid flow) (unit: meter)

u fluid volume flow rate (unit: m/s)

10 ρ fluid density (unit: kg/m³)

g acceleration of gravity (unit: m/s²)

$Const$ a constant value

When wind moves state point 1 (u_1, p_1, Z_1) to state point 2 (u_2, p_2, Z_2), according to the law of conservation of energy, considering any resistance loss during fluid flow, the relationship between the total energy of the wind at the state point 1 and the total energy of the wind at the state point 2 can be expressed in the formula below:

15

$$\frac{\bar{u}_1^2 \alpha_1}{2} + \frac{p_1}{\rho} + g Z_1 + h_e = \frac{\alpha_2 \bar{u}_2^2}{2} + \frac{p_2}{\rho} + g Z_2 + h_f$$

20

wherein, the definitions and units of the symbols in the above formula are:

P fluid pressure (unit: Pa)

α kinetic energy correction factor

Z distance (change in vertical height during fluid flow) (unit: meter)

25 h_f resistance loss during fluid flow (unit: J/kg)

u fluid volume flow rate (unit: m/s)

ρ fluid density (unit: kg/m³)

h_e external mechanical energy added during fluid flow (J/kg)

g acceleration of gravity (unit: m/s²)

Thus, as expressed in the above formula, when wind moves from state point 1 (u_1, p_1, Z_1) to state point 2 (u_2, p_2, Z_2), the wind speed, pressure and height will comply with the law of conservation of energy. Thus, the changes in movement speed and height might compensate the static pressure energy of the wind, and accordingly enable the wind to flow from a low-pressure point to a high-pressure point. Nevertheless, it is more likely for wind to flow from a high-pressure point to a low-pressure point.

During wind movement, as the speed, pressure and temperature of the wind change, the direction of liquid (e.g., water) absorption at the air-soil interface changes accordingly. During wind movement, the absolute humidity (H) of wind can be expressed in the formula below:

$$H = 0.622 \frac{p}{P - p}$$

wherein P indicates the total atmospheric pressure of the flowing wind; p indicates the water vapour pressure inside the flowing wind. It is apparent from the above formula that the absolute humidity (H) of air changes according to the total air pressure and the water vapour pressure.

The relative humidity (RH) of air reflects the air's liquid-absorption capability. At a certain total pressure and temperature of the air, the RH of the air can be expressed in the formula below:

$$\phi = \frac{p}{p_s} * 100\%$$

wherein, ϕ indicates the relatively humidity (RH) of the air; p indicates the water vapour pressure inside the air; p_s indicates the saturated water vapour pressure of air at a given pressure and temperature.

The relationship between temperature “ t ” and p_s can be expressed in the formula below:

$$p_s = \frac{2}{15} \exp \left(18.5916 - \frac{3991.11}{t - 233.94} \right)$$

The relationship between the absolute humidity (H) and relative humidity (RH) ϕ can be expressed in the formula below:

$$H = 0.622 \frac{\phi p_s}{P - \phi p_s}$$

$$\phi = \frac{HP}{(H + 0.622)p_s}$$

The relationship between Dew Point t_d and the total atmospheric pressure p of the air can be expressed in the formula below:

$$t_d = \frac{3991.11}{16.58 - \ln p} - 233.84$$

As shown in the above formulas, during wind movement:

(1) When the absolute humidity H stays the same and the temperature t increases, the water vapour pressure p_s increases, and the relative humidity (RH) of air ϕ decreases. Accordingly, the water absorption capability of the air increases. If the temperature t decreases, the water vapour pressure p_s decreases, and the relative humidity (RH) of air ϕ increases, decreasing the water absorption capability of the air;

20

(2) When there is no water supply to the air, once the total atmospheric pressure of the flowing wind P increases, the dew point t_d of the air will increase. When the dew point t_d of the air is higher than the actual

temperature of the air, water will precipitate from the air. However, for wind that has a very low water content, as both the total atmospheric pressure of the flowing wind P and the temperature t of the wind increase, the increase in the dew point t_d of the air is less than the increase in the temperature t of the air, accordingly there will be no water precipitating from the air. In contrast, if there is little increase in the RH of the air ϕ , the wind will then absorb water from the areas it flows through, damaging the ecology of those areas.

(3) If there is no supply of water to the wind, when the wind moves from a low-temperature and low pressure area to a high-temperature and high-pressure area, the RH of the wind ϕ will decrease as the wind moves, and absorb water away from lands it passes through.

(4) In a low-temperature and low-pressure area where there is adequate water supply to the air, when such air moves towards a high-pressure area, if the temperature does not change much, water will precipitate from the air during its movement. If there is insufficient water supply to the air, the air will function as a “water pump” to absorb water away from lands when the air moves from a low-temperature and low-pressure area to a high-temperature and high-pressure area.

(5) It is clear from the definitions of H (absolute humidity), RH (relative humidity) ϕ and t_d (dew point) of the wind that: at a low-temperature and low-pressure area, both the temperature t is low and the t_d (dew point) decreases. However, with regards to the RH ϕ , the effect of air pressure decrease is larger than the effect of temperature t decrease. Thus, it is likely that such wind will absorb water from the surface of a water source (e.g., soil). This kind of low- RH wind in a low-temperature and low-air pressure environment is also capable of absorbing water from the land surface.

Thus, dynamically controlling factors such as absolute humidity (H), relative humidity (RH), temperature, and air pressure of the wind can regulate the direction of water absorption at the air-soil interface.

- 5 Measuring these factors of the wind can help estimate the direction of water absorption at the air-soil interface, and accordingly identify the “inflection zone” wherein the direction of water absorption shifts from “air-to-soil” to “soil-to-air”.
- 10 In a further embodiment of the invention, the “inflection zone” is a location where there is moving wind (e.g., Plateau platform monsoon, hill valley wind, river valley wind and foehn wind) that has a stable direction and a stable speed, and there is substantial difference between the temperatures of the water surface (e.g., river, lake, stream, sea) and the land of the river bank
- 15 areas. In a further embodiment of the invention, where the plateau platform monsoon moves from a low-temperature and low-pressure area to a downwind area (i.e., an area in the direction toward which the wind is blowing), the changes in temperature and pressure can cause the relative humidity (HR) of the wind ϕ
- 20 to drop so much that the moving wind starts to absorb water away from soils, creating an “inflection zone” that can be used as a reference for choosing the installation location for the wind-powered liquid atomization system 200.

Artificial Permafrost

- 25 In another embodiment of the invention, in order to further alleviate the desertification, degradation and salinization of lands caused by dry wind (particularly during winter), a layer of artificial permafrost is created and placed on those damaged lands, and a liquid atomization system 100 is installed at an “inflection zone” wherein the direction of water absorption
- 30 changes from “air-to-soil” to “soil-to-air”. As the liquid atomization system 100 moisturizes the dry wind passing through, the atomized water droplets were then carried by the wind and scattered over the artificial permafrost that can

effectively capture and store those water droplets, accordingly enriching the humidity of the soils and facilitating the restoration of lands over time. In some further embodiments of the invention, plants such as trees and grasses are planted on the moisturized soils to further facilitate the environmental restoration and recovery, as plants can function to help retain water and hold soils together.

Method for Irrigating

The present invention also discloses a method to alleviate the damaging effects of dry wind as well as to facilitate the restoration and recovery of lands damaged by dry wind. As illustrated in Figure.8, in one embodiment of the invention, the method might first involve determining an “inflection zone” wherein the direction of water absorption shifts from “air-to-soil” to “soil-to-air” (801). The “inflection zone” is in general determined based on measuring the various parameters of the airflow at the location of interest such as barometric pressure P , water vapour pressure p , saturated water vapour pressure p_s , height, temperature t , absolute humidity H , relative humidity ϕ , dew point t_d , speed, wind direction and wind shear.

Once the “inflection zone” is identified, a liquid atomization system is installed at the “inflection zone” to prevent any change in the direction of water absorption at the soil-and-air interface to ensure that water flows from air to soil (i.e., air-to-soil direction) (802).

The liquid atomization system is connected to a water source, such as river, natural or artificial water reservoir, groundwater, stream, creek, well, lake, pond and sea. In a further embodiment wherein the water source is a river, creep or stream, a downward “stair-style” impoundment is created on the bed of the river, creep or stream in order to facilitate the water supply to the liquid atomization system (803) by separating debris and impurities from the water source. In a further embodiment wherein the water source is a river valley with a curved corner, the water inlet of the pump of the liquid atomization system

100 is placed at the upstream of the curved corner to facilitate the water supply to the liquid atomization system 100.

5 In a further embodiment of the invention, in order to further improve the restoration and recovery of the damaged lands (particularly during winter), a layer of artificial permafrost is created and formed on top of the damaged lands (804). The artificial permafrost can effectively capture and retain the atomized water droplets sent from the liquid atomization system 100 via wind. This step could enhance the humidification of the damaged soil and expedites
10 the environmental restoration.

In a further embodiment of the invention, in order to further improve the restoration and recovery of the damaged lands, vegetation or plants such as trees and grasses are planted on the damaged lands once the liquid
15 atomization system 100 has effectively moisturized the damaged lands and elevated the level of underground water (805). Those plants can function to retain the water and hold the soil together, and accordingly further facilitate the restoration and recovery of the damaged lands.

20 In some embodiments, some of the steps illustrated in Figure 8 may be optional in implementing the liquid atomization system 100. For example, the step of constructing a downward “stair-style” impoundment on the streambed (803) is not required if the pump of the liquid atomization system 100 faces no difficulty in taking in clean water from its water source. Also, the step of
25 creating a layer of artificial permafrost (804) might not be necessary if the damaged land can still function to effectively capture and retain water. Moreover, the step of growing plants might not be necessary if the restored and recovered land is capable of retaining soil and water; or wild plants have already started taking roots and growing on those moisturized lands and
30 accordingly there is no need for human intervention in this regard.

In some embodiments, some of the steps as illustrated in Figure 8 can be performed in a different order. For example, in a further embodiment of the invention, the step of constructing a downward “stair-style” impoundment on the streambed (803) and the step of creating a layer of artificial permafrost
5 (804) can be carried out at the same time.

Control System

Another aspect of the present invention also discloses an electronic control system 900 comprising a wind detection module 901 and a control module
10 902. The wind detection module 901 is operable to detect at least one parameter of wind, such as barometric pressure P , water vapour pressure p , saturated water vapour pressure p_s , height, temperature t , absolute humidity H , relative humidity ϕ , dew point t_d , speed, wind direction and wind shear. An example of the wind detection module 901 is an electronic anemometer
15 operable to detect wind speed and convert measurements of the wind speed into digital data. Other examples of the wind detection module 901 include, but not limited to, electronic wind vane (for detecting wind direction), dew point sensor (for estimating dew point), thermometer (for detecting wind temperature) and hygrometer (for detecting humidity of wind).

20 Measurements obtained by the wind detection module 901, in the form of electronic digital data, may be transmitted to the control module 902 using conventional digital data transmission means 911 using a variety of communication protocols. Examples of such digital data transmission means
25 include, but not limited to, copper wires, optical fibres, wireless communication channels, storage media and computer buses.

The control module 902 comprises a central processing unit for processing the received digital data, and a database for storing the received digital data.
30 In a further embodiment of the invention, the control module 902 is a programmable logic controller (PLC). The control module 902 is programmed to analyse the digital data with regards to one or more parameters of the wind,

and is operable to send an electronic command to control and regulate the operation of various components of the liquid atomization system 100 such as the energy source 101, the pump 102, the scaffold 106, the conduit 104, the sprinkler 105 and the additive 109.

5

The electronic command is in general a portion of programming code that is sent from a source to an apparatus, device or equipment over one or more communication channels, the electronic command operable to prompt an apparatus, device or equipment to execute a function. The electronic
10 command can be a segment of programming code that contains steps that need to be executed by the apparatus, device or equipment that receive the segment of code. In this regard, the electronic command can also function as an electronic trigger.

15 In various embodiments of the invention, the control module is configured to send an electronic command (via the communication channel 913) to control the operation of the energy source 101 according to change(s) in one or more wind conditions. For example, once a high wind speed is detected by the wind
20 detection module 901, the data on the wind velocity are then transmitted to the control module 902 (via the communication channel 911) which then analyses the received data and estimates the amount of energy required to increase the outputs (e.g., liquid droplets) of the liquid atomization system 100 so that the flowing wind can be adequately moisturized. The control module 902 then send an electronic command (via the communication channel 913)
25 to operate the energy source 101 to increase its energy output.

In another embodiment of the invention, there are multiple energy sources available to the liquid atomization system 100, comprising at least a main energy source 101a and a backup energy source 101b. If energy output from
30 the main energy source 101a cannot be further increased for moisturizing a high-velocity dry wind, the control module 902 is operable to activate the backup energy source 101b (via the communication channel 914) to provide

additional energy to operate the pump 102 to draw more liquid into the conduits 104.

5 In some embodiments of the invention, the control module 902 is configured to directly command the pump 102 (via the communication channel 912) to adjust the pump speed to control the volume of liquid pumped into the conduits 104. In a further embodiment wherein there is a plurality of pumps, the control module 902 is operable to adjust the number of pumps in operation to control the volume of liquid pumped into the conduits 104.

10

In some embodiments of the invention, the control module 902 is configured to send one or more electronic commands (via the communication channel 915) to determine the type and amount of the additives 109 to be added into the liquid source 103 to adjust the droplet size and density. In a further
15 embodiment of the invention, the various types of additives (e.g., compressed gases, surfactant) are stored in different compartments. The electronic command from the control module 902 can therefore specify which compartment to open and for how long. Examples of surfactant include, but not limited to, stearate, sodium dodecyl benzene sulphonate (SDBS),
20 triethanolamine (TEA) and other similar compounds.

In another embodiment of the invention, the sprinkler 105 comprises a sprinkler control means 903 configured to receive an electronic command from the control module 902 via the communication channel 917. In a further
25 embodiment of the invention, the sprinkler control means 903 is an electromechanically operated valve. In a further embodiment, the sprinkler control means 903 is a solenoid valve. In a further embodiment, the sprinkler control means 903 is an electronic relief valve. In a further embodiment, upon receiving the electronic command from the control module 902, the electronic
30 relief valve will operate to control the operation of the sprinkler 105, optimizing, for example, the density of the liquid droplets so that the liquid

droplets won't aggregate into large liquid drops too fast and are able to travel with the wind for a long distance.

5 In a further embodiment of the invention, the sprinkler control means 903 is configured to activate/deactivate one or more nozzles of the sprinkler 105. For example, when a sprinkler 105 comprises a plurality of different nozzles, such as air atomizing nozzle, fine spray nozzle, hollow cone nozzle, flat fan nozzle, or full cone nozzle. The sprinkler control means 903 is an electronic switch device operable to determine which type of nozzle to be activated (or
10 deactivated) upon receiving an electronic command from the control module 902. For example, when liquid droplet of 20 μm – 200 μm is desired, the control module 902 sends an electronic command to the sprinkler control means 903, which then activates either an air atomizing nozzle or a hydraulic fine spray nozzle. When liquid droplet of larger than 200 μm is desired, the
15 sprinkler control means 903 then activates a hollow cone nozzle, a flat fan nozzle or a full cone nozzle.

In a further embodiment of the invention, the conduit 104 comprises a conduit control means 904 configured to receive an electronic command from the
20 control module 902 via the communication channel 918. In a further embodiment of the invention, the conduit control means 904 is an electromechanically operated valve. In a further embodiment, the conduit control means 904 is a solenoid valve. In a further embodiment, the conduit control means 903 is an electronic relief valve. In a further embodiment, upon
25 receiving the electronic command from the control module 902, the electronic relief valve will operate to control liquid flow inside the conduit 104 to optimize, for example, the density of the liquid droplets so that the liquid droplets won't aggregate into large liquid drops too fast and are able to travel with the wind for a long distance.

30

In a further embodiment of the invention, the scaffold 106 comprises a scaffold control means 905 configured to receive an electronic command from

the control module 902 via the communication channel 919. In a further embodiment of the invention, the scaffold control means 905 is an electromechanically operated revolving platform that holds the scaffold 106. Upon receiving the electronic command from the control module 902 (with regards to for example, wind direction), the revolving platform then adjusts the orientation of the scaffold 106 so that the conduits 104 are perpendicular to the wind direction. In a further embodiment of the invention, the scaffold control means 905 is an electromechanically operated foldable joint configured to fix the stand 106a of the scaffold 106 to a land surface. Upon receiving the electronic command from the control module 902, the foldable joint then tilts the stand 106a to be at an angle Θ to the land surface, wherein Θ is smaller than 90 degree.

In a further embodiment of the invention, the control module 902 is operable to send a plurality of electronic commands to a plurality of components (e.g., energy source 101, pump 102, additive 109, sprinkler control means 903, conduit control means 904 and scaffold control means 905) simultaneously to control the various components of the liquid atomization system 100.

The above is a description of embodiment(s) of an apparatus, system and method for nebulizing water for irrigation. It is to be further appreciated that technical features from one or more embodiments as described may be permuted and/or combined to form further embodiments without departing from the scope of the present invention.

Claims:

1. A liquid atomization system for irrigation, comprising:
 - a liquid pump operable to pump liquid from a liquid source;
 - 5 at least one conduit arranged to receive the liquid from the liquid pump, wherein the at least one conduit includes a plurality of atomizers operable to atomize the liquid received from the conduit;
 - the system further including at least one scaffold comprising at least one stand operable to be affixed onto a surface and a plurality of horizontal
 - 10 bars, wherein the at least one conduit is supported by the plurality of horizontal bars; wherein the at least one scaffold is installed at a land location to enable the atomized liquid that is released by the plurality of atomizers to be carried by wind passing the plurality of horizontal bars.
- 15 2. The liquid atomization system according to claim 1, wherein two adjacent horizontal bars of the plurality of parallel horizontal bars are configured to be spaced apart from each other at a first predetermined distance.
- 20 3. The liquid atomization system according to claim 2, wherein the first predetermined distance is calculated based on at least one parameter of the wind: barometric pressure P , water vapour pressure p , saturated water vapour pressure p_s , height, temperature t , absolute humidity H , relative humidity ϕ , dew point t_d , speed, direction and shear.
- 25 4. The liquid atomization system according to claim 3, wherein the speed ranges from 0.8 m/s to 8 m/s, and the first predetermined distance ranges from 30 cm to 45 cm.
- 30 5. The liquid atomization system according to any one of claim 2 to 4, wherein the first predetermined distance can be dynamically adjusted via a programmable logic controller arranged with an actuator to move the plurality of parallel horizontal bars.

6. The liquid atomization system according to any one of the preceding claims, wherein two adjacent atomizers of the plurality of atomizers are
5 configured to be spaced apart from each other at a second predetermined distance.

7. The liquid atomization system according to claim 6, wherein the second
predetermined distance is calculated based on at least one parameter of the
10 wind: barometric pressure P , water vapour pressure p , saturated water vapour
pressure p_s , height, temperature t , absolute humidity H , relative humidity ϕ ,
dew point t_d , speed, direction and shear.

8. The liquid atomization system according to any one of the preceding
15 claims, wherein the at least one stand is fixed with an angle Θ to the surface,
and the angle Θ is smaller than 90 degree.

9. The liquid atomization system according to any one of the preceding
claims, wherein two adjacent atomizers of the plurality of atomizer are
20 configured to spray the atomized liquid in opposite directions from the scaffold
106.

10. The liquid atomization system according to any of one the preceding
claims, wherein a number of the at least one conduit to be placed on the
25 scaffold is determined based on at least one parameter of the wind:
barometric pressure P , water vapour pressure p , saturated water vapour
pressure p_s , height, temperature t , absolute humidity H , relative humidity ϕ ,
dew point t_d , speed, direction and shear.

30 11. The liquid atomization system according to any one of the preceding
claims, wherein the at least one conduit is placed at least 12 meters above the
surface.

12. The liquid atomization system according to any one of the preceding claims, wherein the liquid pump is powered by an energy source.

5 13. The liquid atomization system according to claim 12, wherein the energy source is a wind-powered generator.

14. The liquid atomization system according to claim 13, wherein the scaffold and the wind-powered generator are integrated into a single apparatus.

10

15. The liquid atomization system according to claim 14, wherein the wind-powered generator comprises a wind tower comprising a tower-top structure, and the scaffold is placed on the tower-top structure.

15 16. The liquid atomization system according to any one of the preceding claims, wherein the liquid pump is a reciprocating pump.

17. The liquid atomization system according to any one of the preceding claims, wherein the liquid pump is operable by either a mechanical force or an
20 electrical force or both.

18. The liquid atomization system according to any one of the preceding claims, wherein the atomizer comprises at least one sprinkler.

25 19. The liquid atomization system according to claim 18, wherein the at least one sprinkler comprises one or more nozzles.

20. The liquid atomization system according to claim 19, wherein the one or more nozzles comprise at least one air atomizing nozzle, at least one fine
30 spray nozzle, at least one hollow cone nozzle, at least one flat fan nozzle, at least one full cone nozzle, at least one hydraulic fine spray, or a combination thereof.

21. The liquid atomization system according to claim 20, wherein the at least one air atomizing nozzle is selected from the group comprising flat spray nozzle, round spray nozzle, wide-angle spray nozzle and external mix nozzle.
- 5
22. The liquid atomization system according to any of claim 18 to claim 21, wherein the at least one sprinkler is operable to atomize the liquid into liquid droplets that have a diameter ranging from 10 μm to 120 μm .
- 10
23. The liquid atomization system according to any one of the preceding claims, wherein the liquid is water, and the liquid source is a water source.
24. The liquid atomization system according to any one of the preceding claims, wherein the at least one conduit is a pipe made of PVC (PolyVinyl Chloride), CPVC (Chlorinated Polyvinyl Chloride), PEX (Cross-linked polyethylene), copper, carbon steel or any combination thereof.
- 15
25. The liquid atomization system according to any one of the preceding claims, wherein the diameter of the at least one conduit ranges from 8 mm to 50 mm.
- 20
26. The liquid atomization system according to any one of the preceding claims, wherein the liquid moves inside the at least one conduit at a speed ranging from 1.8 m/s to 8 m/s.
- 25
27. The liquid atomization system according to any one of the preceding claims, wherein a plurality of the at least one conduit is assembled using a plurality of quick connectors.
- 30
28. The liquid atomization system according to any one of the preceding claims, where one or more additives are added in the liquid source.

29. The liquid atomization system according to claim 28, wherein the one or more additives comprise at least one compressed gas and/or at least one surfactant.

5 30. The liquid atomization system according to claim 29, wherein the surfactant is selected from the group comprising stearate, sodium dodecyl benzene sulphonate (SDBS) and triethanolamine (TEA).

10 31. The liquid atomization system according to claim 30, wherein the surfactant is added into the liquid source at a proportion by weight of 10 to 320 ppmw (parts per million by weight).

15 32. The liquid atomization system according to any one of the preceding claims, further comprising a wind detection module operable to detect at least one parameter of the wind, and a control module configured to receive the at least one parameter from the wind detection module.

20 33. The liquid atomization system according to claim 32, wherein the control module is configured to control the operation speed of the liquid pump.

34. The liquid atomization system according to any one of the preceding claims, wherein the at least one conduit comprises one or more valves.

25 35. The liquid atomization system according to any one of the preceding claims, wherein each of the plurality of atomizers comprises one or more valves.

30 36. A method for installing a liquid atomization system for irrigation at a location where there is wind flowing through, comprising the steps of:
(a) installing at least one energy source, at least one liquid pump and at least one scaffold comprising at least one stand operable to be affixed onto a surface and a plurality of horizontal bars;

(b) connecting the energy source to power the liquid pump that is configured to pump liquid from a liquid source;

(c) connecting the liquid pump to at least one conduit comprising a plurality of atomization means;

5 (d) placing the at least one conduit on the plurality of horizontal bars.

37. A method according to claim 37, further comprising a step of separating two adjacent horizontal bars from the plurality of horizontal bars from each other at a first predetermined distance.

10

38. A method according to claim 36 or claim 37, further comprising a step of separating two adjacent atomization means of the plurality of atomization means from each other at a second predetermined distance.

15 39. A method according to any of claims 36 to 38, further comprising a step of measuring at least one parameter of the wind for determining the location: barometric pressure P , water vapour pressure p , saturated water vapour pressure p_s , height, temperature t , absolute humidity H , relative humidity ϕ , dew point t_d , speed, direction and shear.

20

40. A method according to claim 37, further comprising a step of measuring at least one parameter of the wind for determining the first predetermined distance: barometric pressure P , water vapour pressure p , saturated water vapour pressure p_s , height, temperature t , absolute humidity H , relative
25 humidity ϕ , dew point t_d , speed, direction and shear.

41. The method according to claim 40, further comprising a step of arranging the first predetermined distance to range from 30 cm to 45 cm for the speed of 0.8 m/s to 8 m/s.

30

42. A method according to claim 38, further comprising a step of measuring at least one parameter of the wind for determining the second predetermined

distance: barometric pressure P , water vapour pressure p , saturated water vapour pressure p_s , height, temperature t , absolute humidity H , relative humidity ϕ , dew point t_d , speed, direction and shear.

- 5 43. A method according to any of claims 36 - 42, further comprising a step of calculating the absolute humidity H from the water vapour pressure p and the barometric pressure P based on a formula expressed as:

$$H = 0.622 \frac{p}{P - p}$$

- 10 44. A method according to any of claims 36 - 43, further comprising a step of calculating the relative humidity ϕ from the water vapour pressure p and the saturated water vapour pressure p_s based on a formula expressed as:

$$\phi = \frac{p}{p_s} * 100\%$$

- 15 45. A method according to any of claims 36 - 44, further comprising a step of calculating the saturated water vapour pressure p_s from the temperature t based on a formula expressed as:

$$P_s = \frac{2}{15} \exp \left(18.5916 - \frac{3991.11}{t - 233.94} \right)$$

20

25

46. A method according to any of claims 36 - 45, further comprising a step of calculating the relative humidity ϕ from the absolute humidity H , the water vapour pressure p and the saturated water vapour pressure p_s based on a formula expressed as:

$$\phi = \frac{HP}{(H+0.622)p_s}$$

5

47. A method according to any of claims 36 - 46, further comprising a step of calculating the dew point t_d from the water vapour pressure p based on a formula expressed as:

$$t_d = \frac{3991.11}{16.58 - \ln p} - 233.84$$

10

48. A method according to any of claims 36 - 47, further comprising a step of constructing a downward stair-style impoundment in a streambed as the liquid source.

15

49. A method according to any of the claims 36 - 48, further comprising a step of creating a layer of artificial permafrost on a land damaged by the wind.

50. A method according to any of the claims 36 - 49, further comprising a step of growing a plurality of plants on a land damaged by the wind.

20