Fog collection potential for domestic rural use and irrigation in San Cristóbal Island, Galápagos, Ecuador

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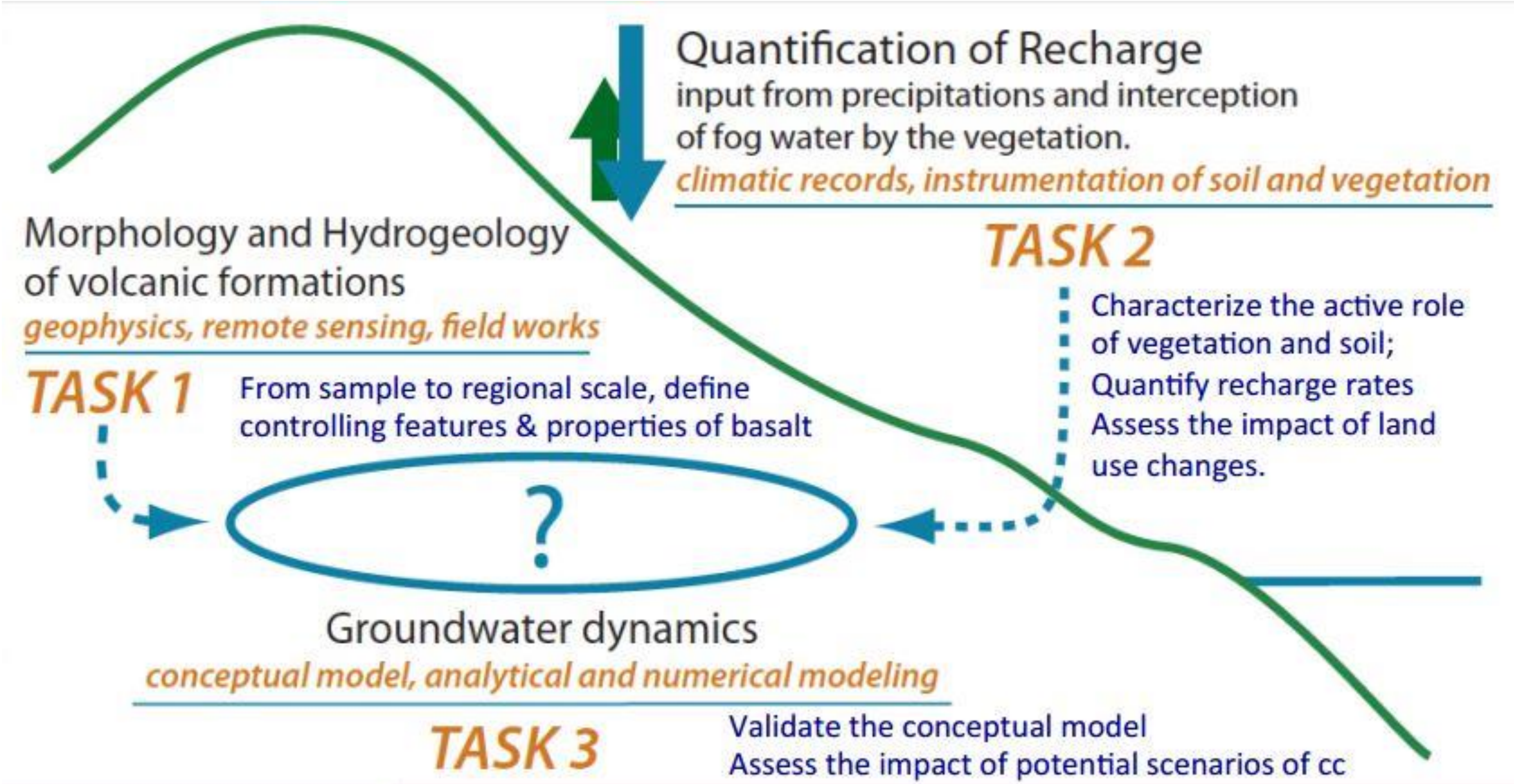
Introduction

Galápagos Islands Integrated Water Studies (GIIWS)

Scientific and technical objectives of the project:

- Improving the understanding of hydrogeology in tropical basaltic islands,
- Show the invaluable contribution of joint research in hydrological and ecological sciences to increase understanding of ecosystem functioning and contribute to their restoration in sensitive areas,
- Addressing local challenges of conservation, protection and sustainable development of natural resources through the joint action of researchers and local actors (GIIWS,2016).

Introduction



Galápagos Islands Integrated Water Studies (GIIWS) Project (Image taken from GIIWS, 2010)

Introduction

Galápagos

Semi-arid zone

Scarce superficial water resources

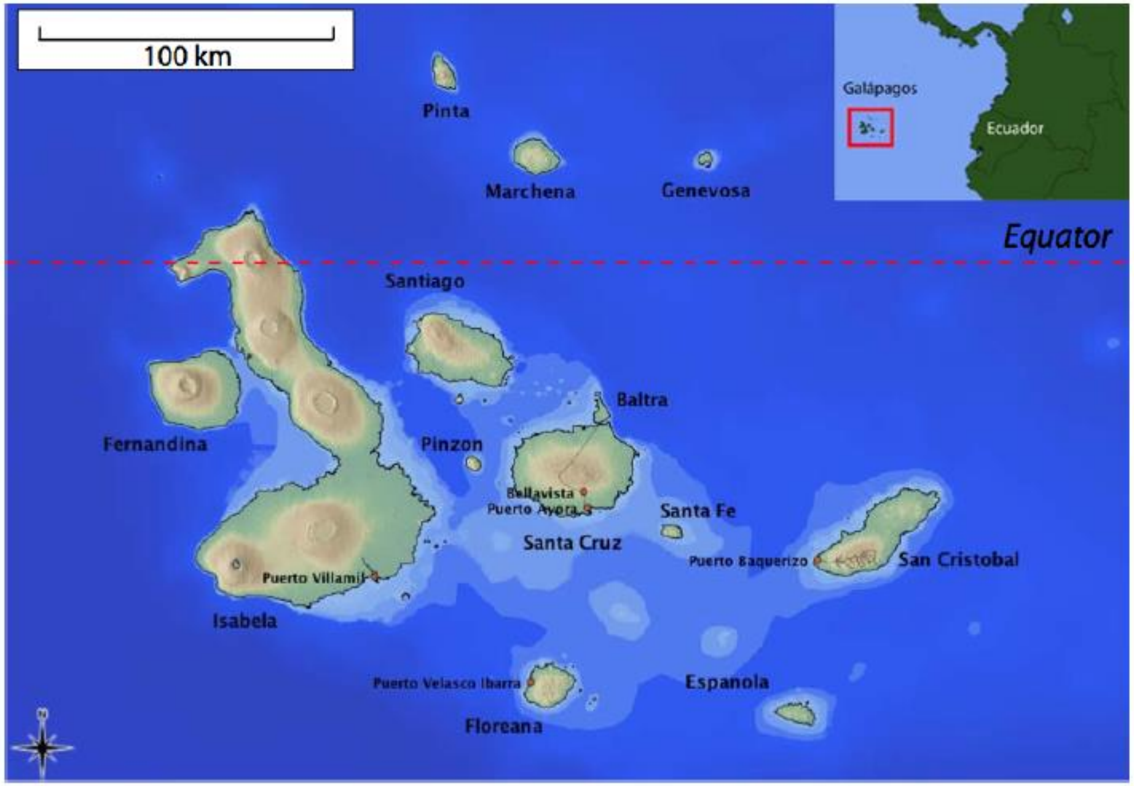
- Productive activities
- Life quality
- Increase of popualtion and tourism

ALTERNATIVE

Study zone

Galápagos

- At 1000 km East of mainland
- Atypic climatic conditions
- Two seasons
  - Cold garúa season
  - Hot invierno season



The Galápagos Islands (Pryet, 2011)

Study zone

Cold garúa season (Jun-Dec)

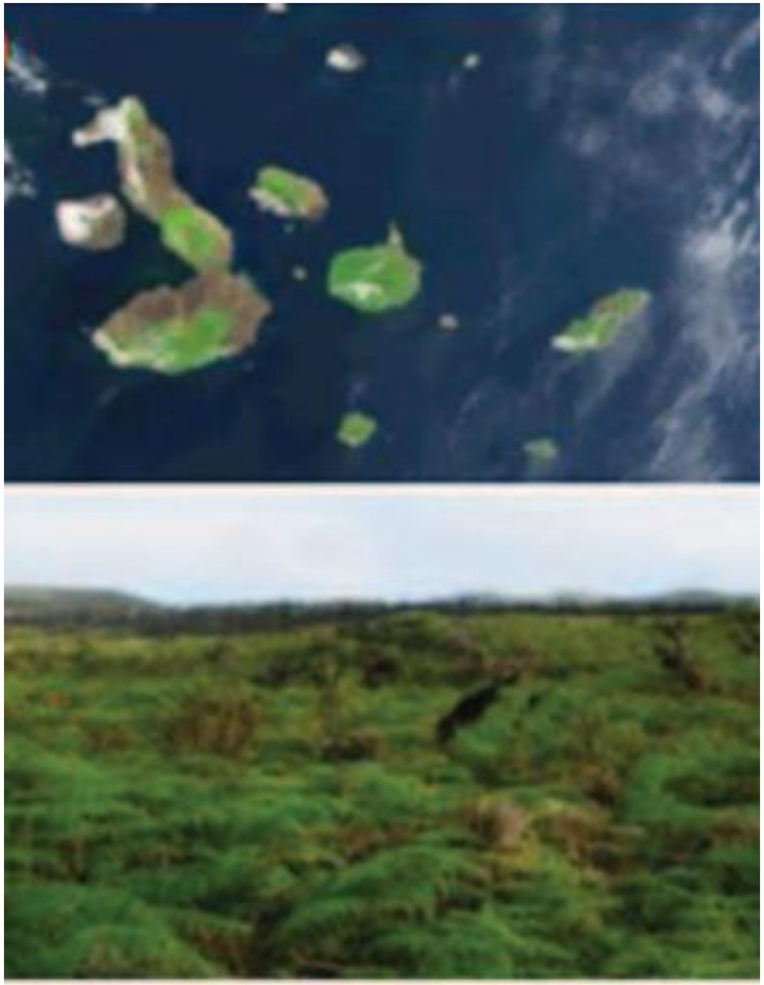
- Temperature Inversion layer
- Cold air masses trapped below hot air masses
- Condensation of air humidity on vegetation leaves

Galápagos Archipelago and windward side of Santa Cruz Island in cold garúa season, (Image taken from Google Earth, 2012) (González, 2013)

Study zone

Hot invierno season (Jan-May)

- High air and ocean temperatures
- Convective rainfalls



Galápagos Archipelago and windward side of Santa Cruz Island in hot invierno season, (Image taken from Google Earth, 2012) (González, 2013)

Study zone

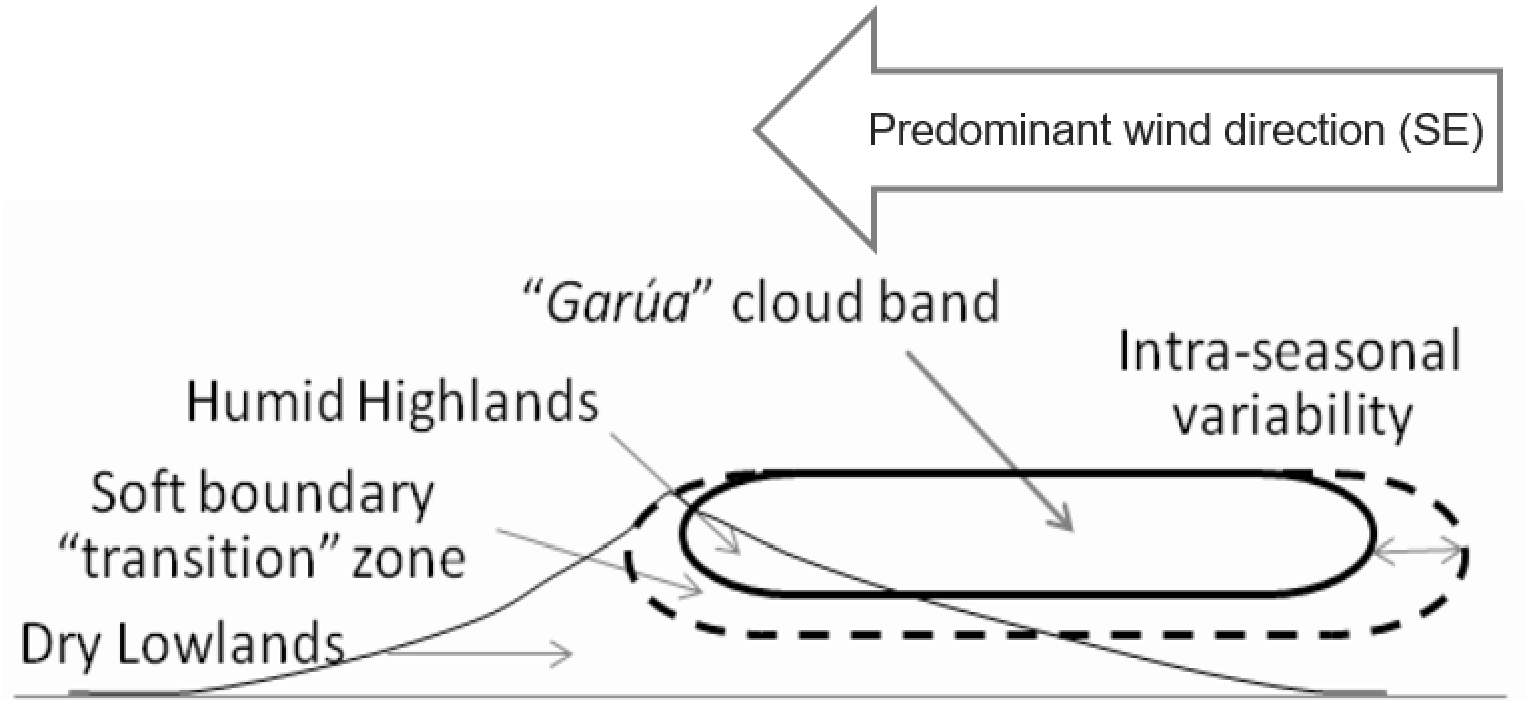


Figure 3. Climatic zonation in garúa season (Trueman & d'Ozouville, 2010)

Study zone

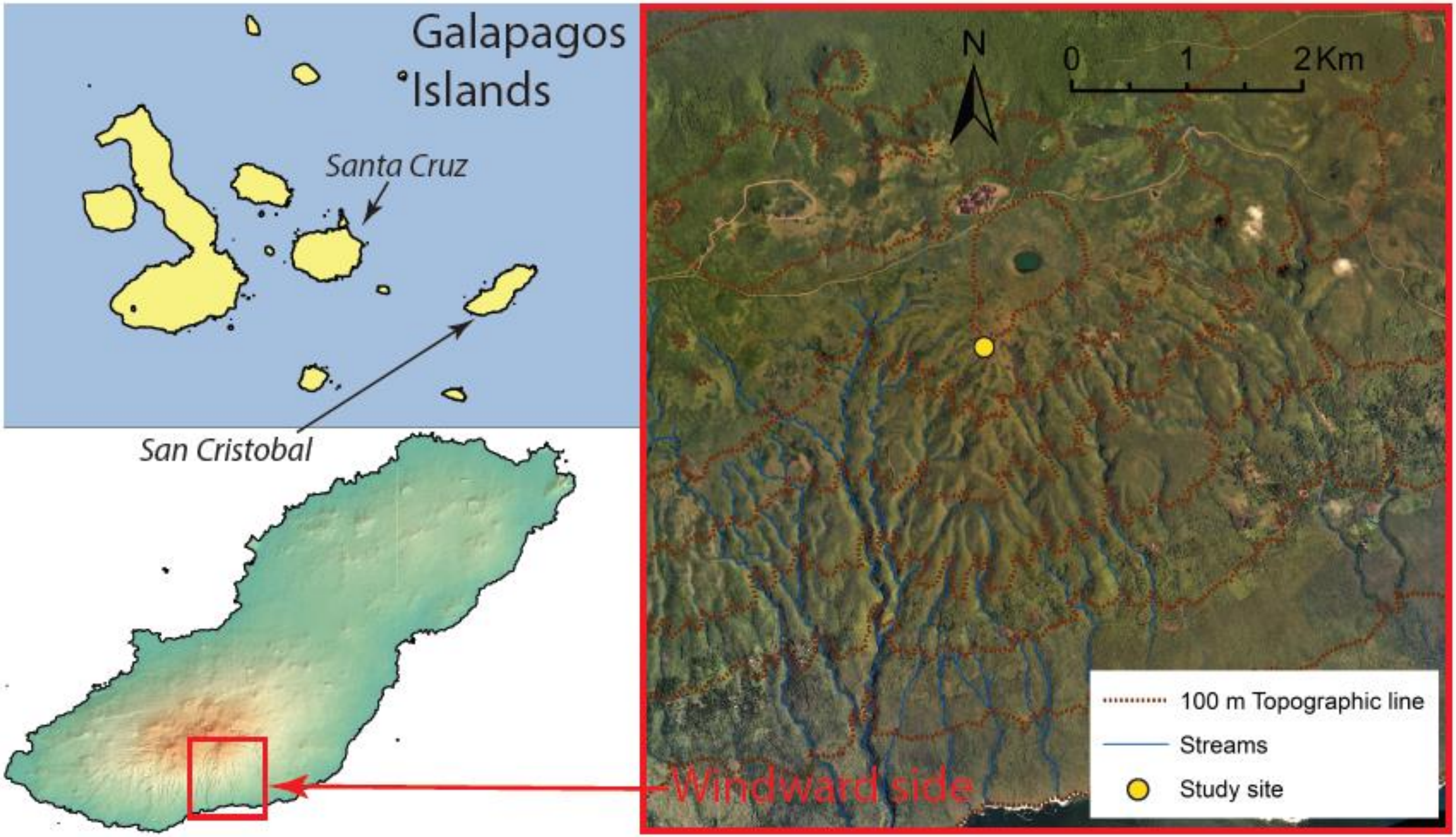


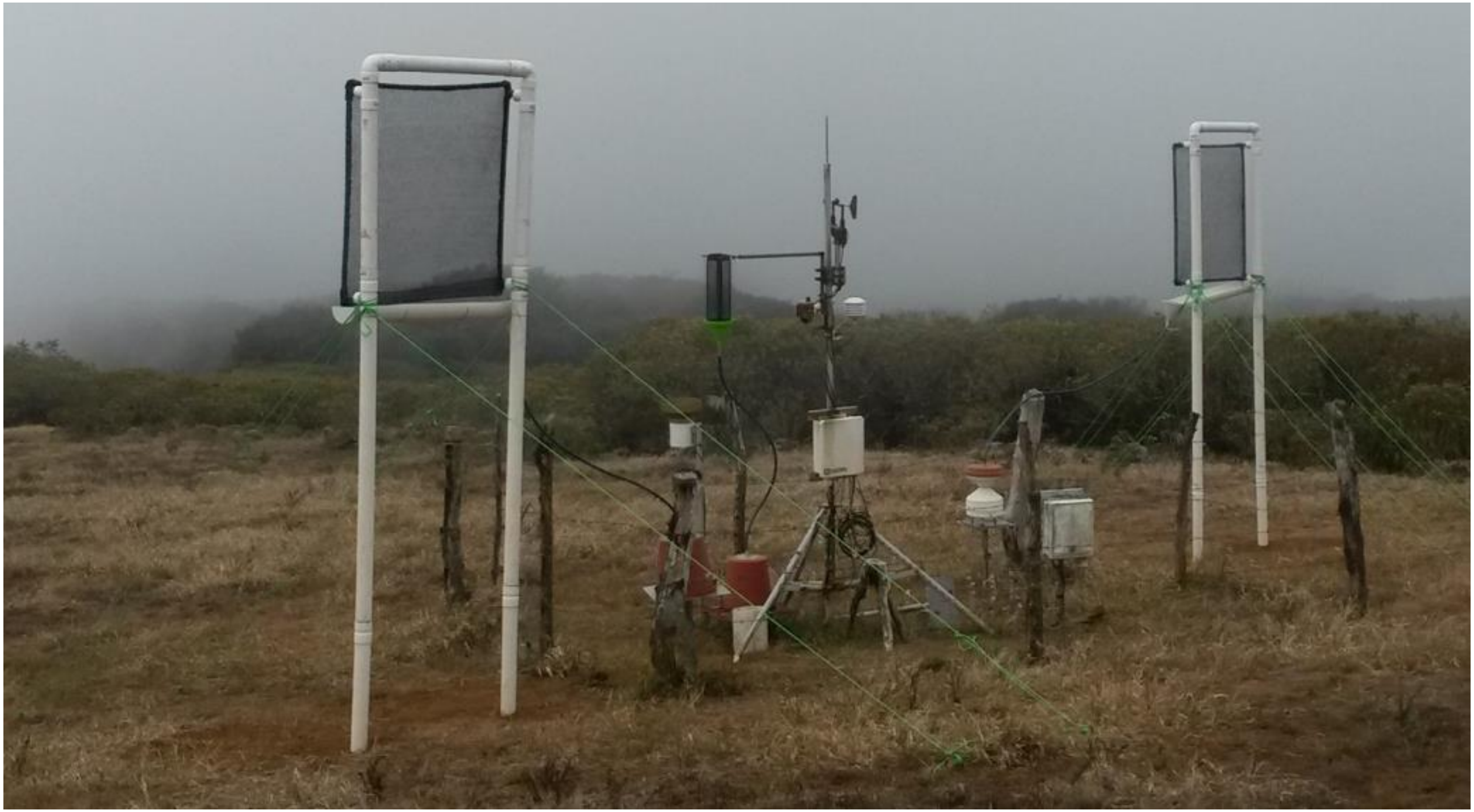
Figure 4. Study zone in the windward side of San Cristobal Island at 600 m of elevation (Image taken from IGM (2014)**)** (Domínguez, 2016)

Methodology

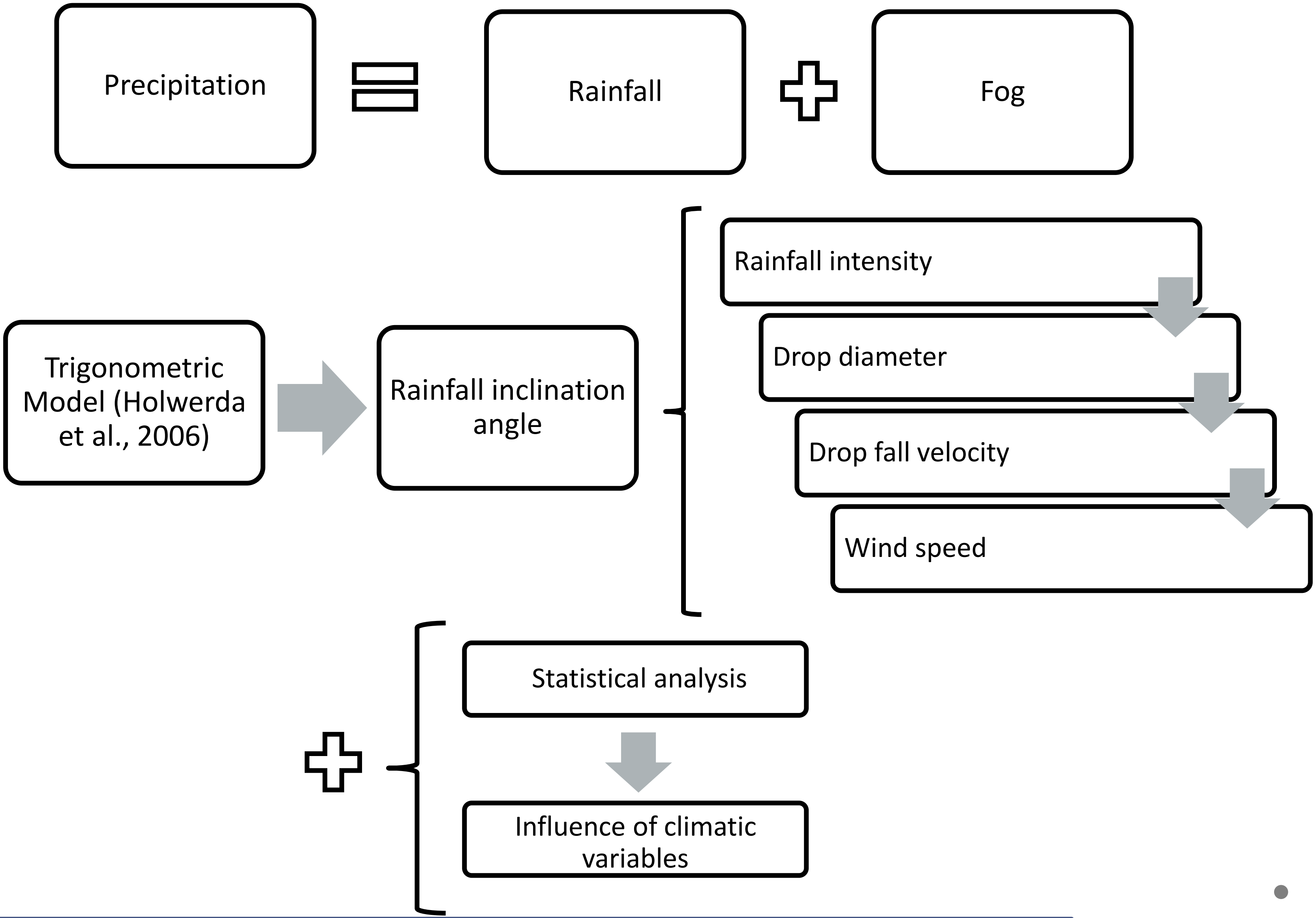
Variable	**Equipment**	**Model**	**Measurement**
Data recording	Datalogger	*Campbell CR1000*	
Solar radiation, relative humidity, air temperature	Silicone Pyranometer Sensor	*Kipp & Zonen SPLite* *Campbell CS215 T&RH*	2 m
Wind speed and direction	Anemometer	*Young Wind Sentry Kit*	2 m
Precipitation	Pluviometer	*Texas TE525MM*	1.5 m

Colector	**Equipment**	**Model**	**Measurement**
SFC, polyethylene mesh of 35% shade coefficient	Pluviometer	*Précis Mécanique R307A0*	2 m
SFC, polyethylene mesh of 50% shade coefficient	Pluviometer	*Précis Mécanique R307A0*	2 m
CFN, plastic mesh of 1 mm	Pluviometer	*Précis Mécanique R307A0*	2 m

Methodology



Methodology



Methodology

Water offer and demand

Water consumption 44.2 hm3
- Domestic consumption
- Livestock
- Agriculture → 99.6%

Hydrological balance
- Average year (2013-2014)
- Dry year

Crop coefficient (k) (FAO,2006)
- Coffee (74%)
- Others (26%)

$$k_{coffee} = 0.93$$

$$k_{SC} = 0.74$$

Water for agriculture
- Elevation ranges (100 m)
- ↓ Water deficit
- ↓ % deficit covered (35-SFC)

Results

Climatic conditions in 48 day period of study (June-July, 2016)	
Average temperature	18.2 °C
Average wind speed	2.5 m/s
Average wind direction	199 °
Precipitation	72 mm

Fog quantification

Collector	Fog heigh (mm)	Fog (L/m²/day)
35-SFC	654	13.6
50-SFC	380	7.9
CFN	165	3.4

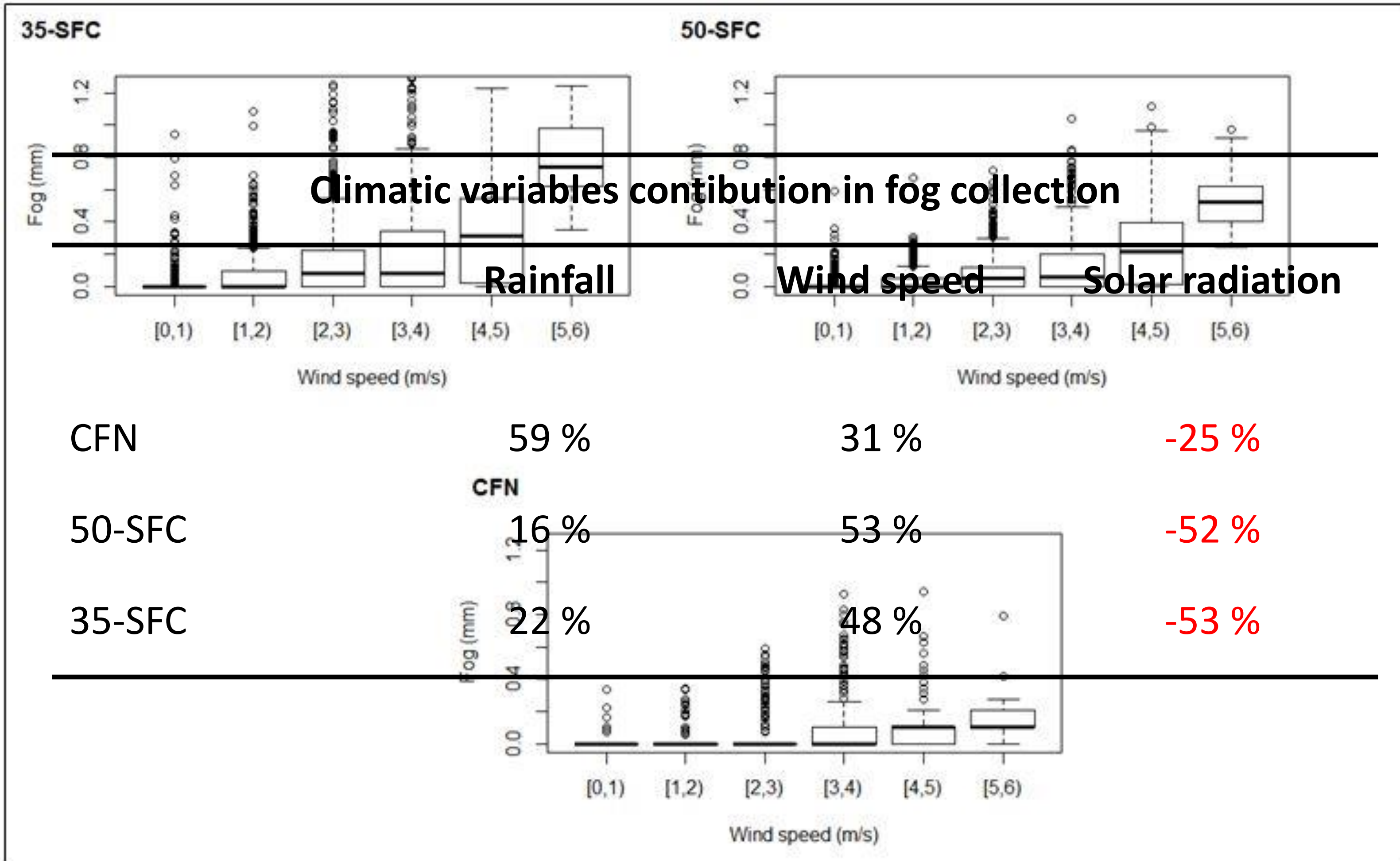
Correlation between fog collectors

Volumen	**CFN**	**50-SFC**	**35-SFC**
CFN	1	0.90	0.81
50-SFC		1	0.94
35-SFC			1

Fog	**CFN**	**50-SFC**	**35-SFC**
CFN	1	0.75	0.69
50-SFC		1	0.91
35-SFC			1

Results

Driving factors in fog collection

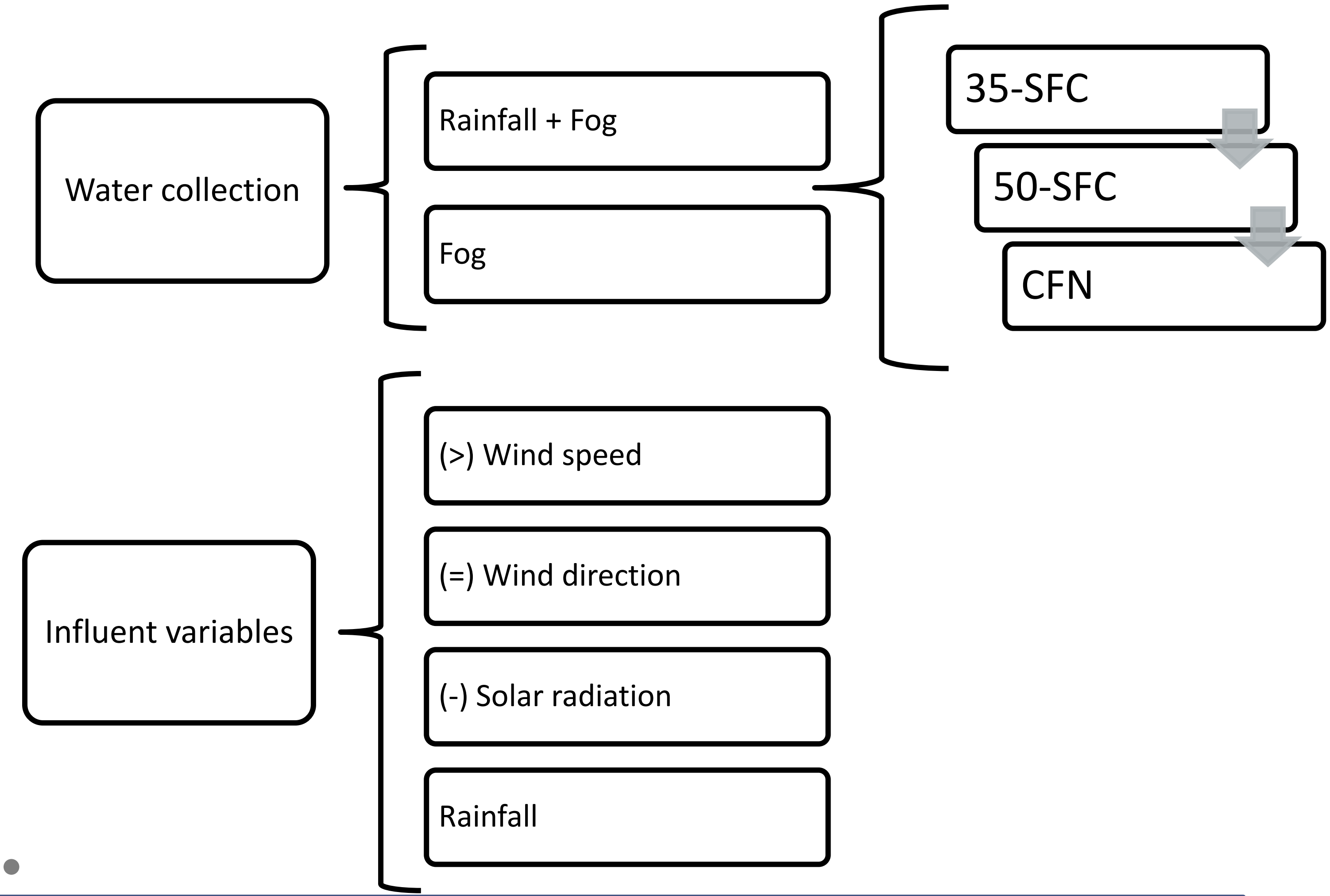


Climatic variables contibution in fog collection

	Rainfall	Wind speed	Solar radiation
CFN	59 %	31 %	-25 %
50-SFC	16 %	53 %	-52 %
35-SFC	22 %	48 %	-53 %

Discussion

Driving factors in fog collection



Discussion

Sitio	Neblina (L/m²/día)
San Cristóbal-Ecuador	8.3
Chile	3
Perú	9
Omán	30
Brand se Baai-South Africa	0.4
Kalkbaken se Kop-South Africa	1.3
Cape Columbine-South Africa	2.4
Canary Islands (feb-jul)	2.6
Canary Islands (ago-ene)	1.1
Mauna Loa-Hawaii (2530 m)	1.9
Mauna Loa-Hawaii (1580 m)	2.1
Sierra Madre-México(1330 m)	0.4
Sierra Madre-México (1900 m)	1.6
†Venezuela	1.2

West coast of South Africa

Discussion

Water offer and demand

	Average year	Dry year
Deficit (0-100 m)	June, and from December to May	
Drought (0-700 m)	March	March, April, May
Higher fog collection potential	August, September and October	
Water deficit	9.1 L/s	10.4 L/s

Discussion

Average year

Domestic consumption

Dry year

Water deficit irrigation

25 % of deficit

9.1 L/s

70 SFC of 35% shade coefficient

Farm of 35 habitants

48 m^2

100 % of water supply

1000 L/día

3 SFC of 35% shade coefficient

Water deficit irrigation

24 m^2

25 % of deficit

10.4 L/s

80 SFC of 35% shade coefficient

48 m^2

Conclusions

- 35-SFC is the most effcient in terms of fog collection, each farm could install a fog collectors system according to its needs.
- From this study and based on the obtained results, it has been proven that the use of this devices can contribute to the water supply and to enhance the productive activities in Galápagos.
- It is possible to apply this alternative in other inhabited islands of the archipelago such as Santa Cruz, Isabela y Floreana, where the water scarcity is worse, because of lacking superficial water sources.

GIIWS
GALAPAGOS ISLANDS INTEGRATED WATER STUDIES

ESCUELA POLITÉCNICA NACIONAL

Thanks!

Model

- Rainfall intensity (mm/h)
- Drop diameter D (mm) (Holwerda et al., 2006; Laws & Parsons, 1943)

$$D = 2.23(0.03937R)^{0.102}$$

- Drop fall velocity V (m/s) (Gunn & Kinzer, 1949; Holwerda et al., 2006)

$$V = 3.378\ln(D) + 4.213$$

- Rainfall inclination angle b (Herwitz & Slye, 1995; Holwerda et al., 2006):

$$\tan(b) = U/V$$

- Actual rainfall for each time step (Domínguez, 2016):

$$RF_a = RF_v / \cos(b)$$

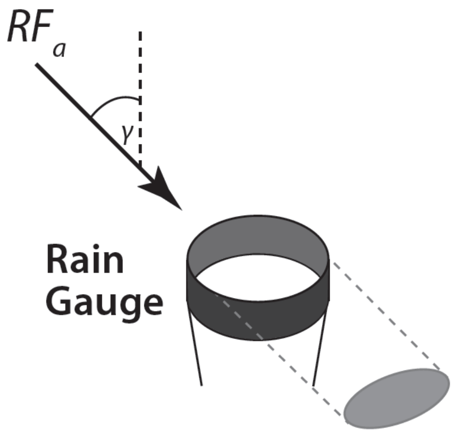
- Volume of actual rainfall in the collector (Domínguez, 2016):

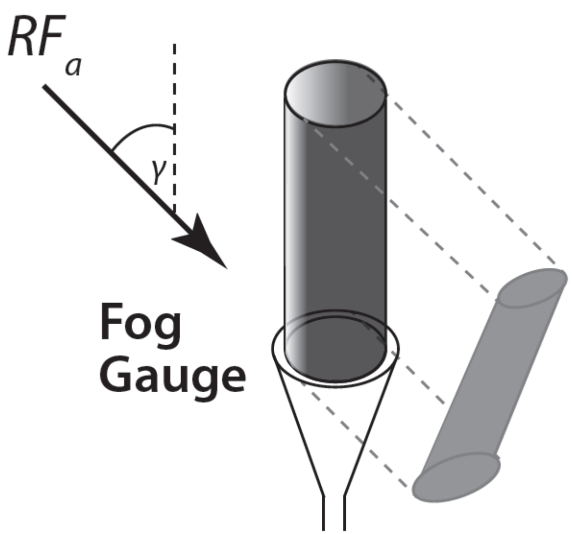
$$VF_r = RF_a * S_e$$

- Fog (mm)

$$F = (VF_T - VF_r) / A_c$$

Methodology





$$RF_a = RF_v / \cos(b)$$

$$VF_r = RF_a * S_e$$

$$F = (VF_T - VF_r) / A_c$$

Contribution of climatic variables in fog collection

Influence of climatic variables variables in the fog collection, through a quantitative analysis proposed by Sicart, Hock, & Six (2008):

$$r(x_{i,}, Fog) = \sum_i \frac{\sigma_{x_i}}{\sigma_{Fog}} r(x_i) \,, \quad (7)$$

where σ_{x_i} is the standard deviation of the climatic variable, σ_{Fog} is the standard deviation of fog and $r(x_i)$ is regression coefficient between the climatic variable and fog.