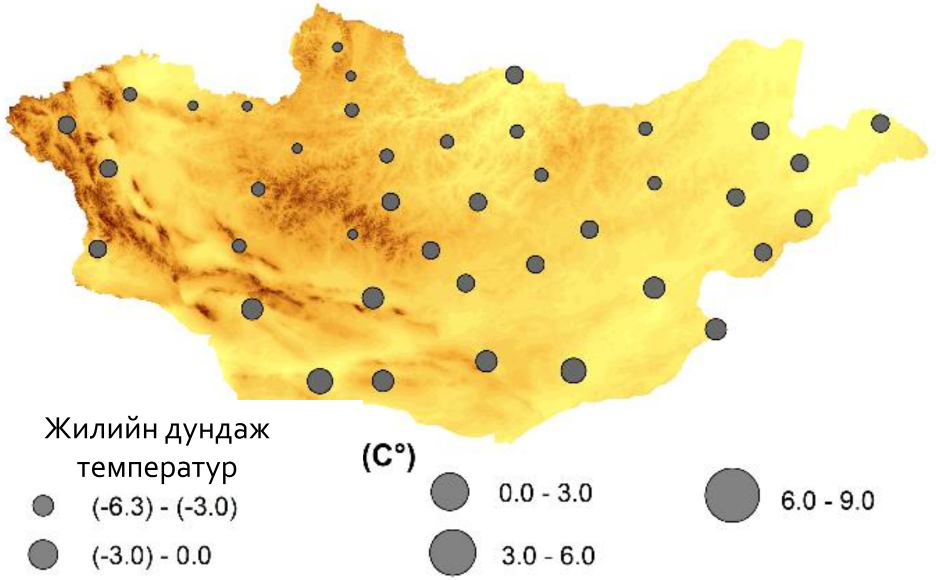
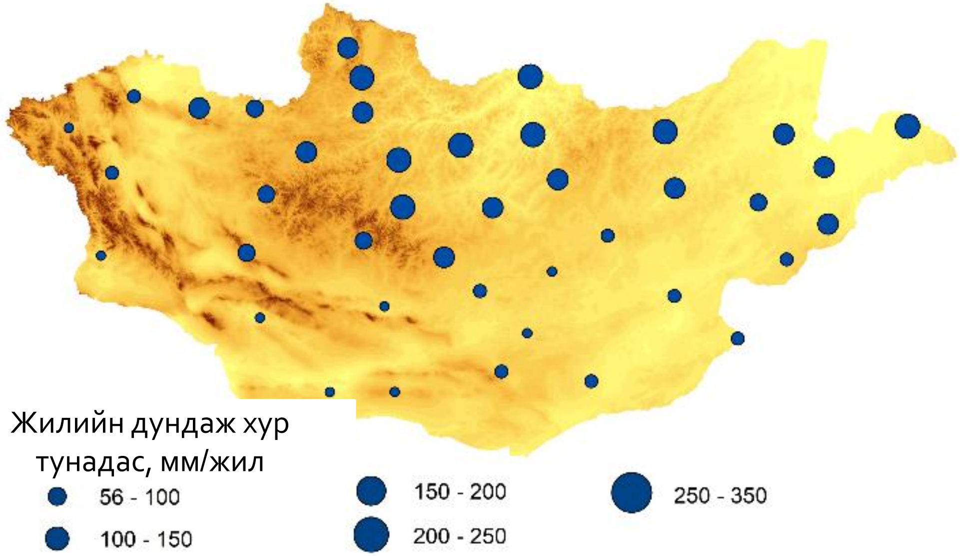
МОНГОЛ ОРНЫ ГАЗРЫН ДООРХ УСНЫ ТЭЖЭЭМЖИЙГ УСААР ХАНААГҮЙ БҮСИЙН ЗАГВАРЧЛАЛ АШИГЛАН ТООЦООЛОХ НЬ

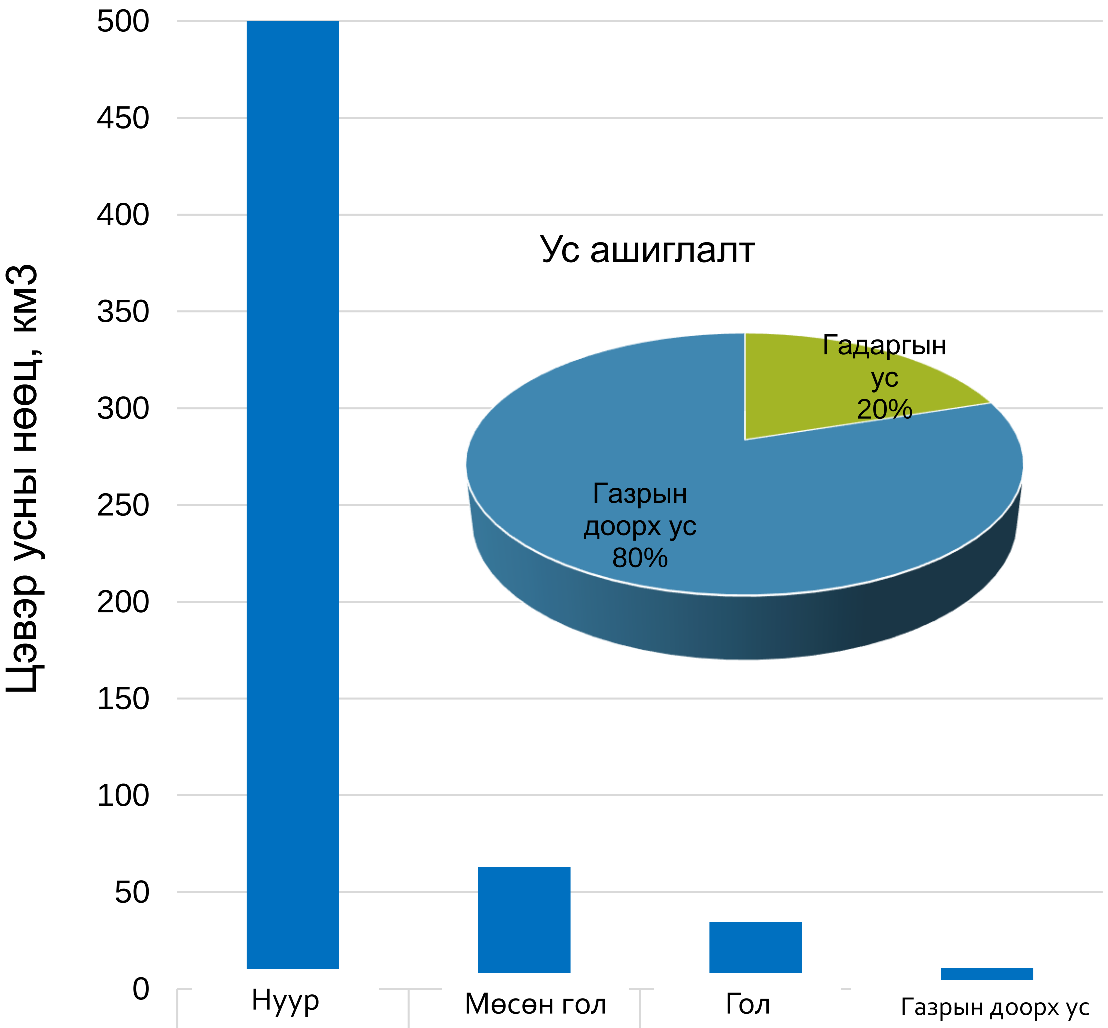
Б.Хулан

Гидрогеологич, Тригтек ХХК

СУДАЛГААНЫ ҮНДЭСЛЭЛ





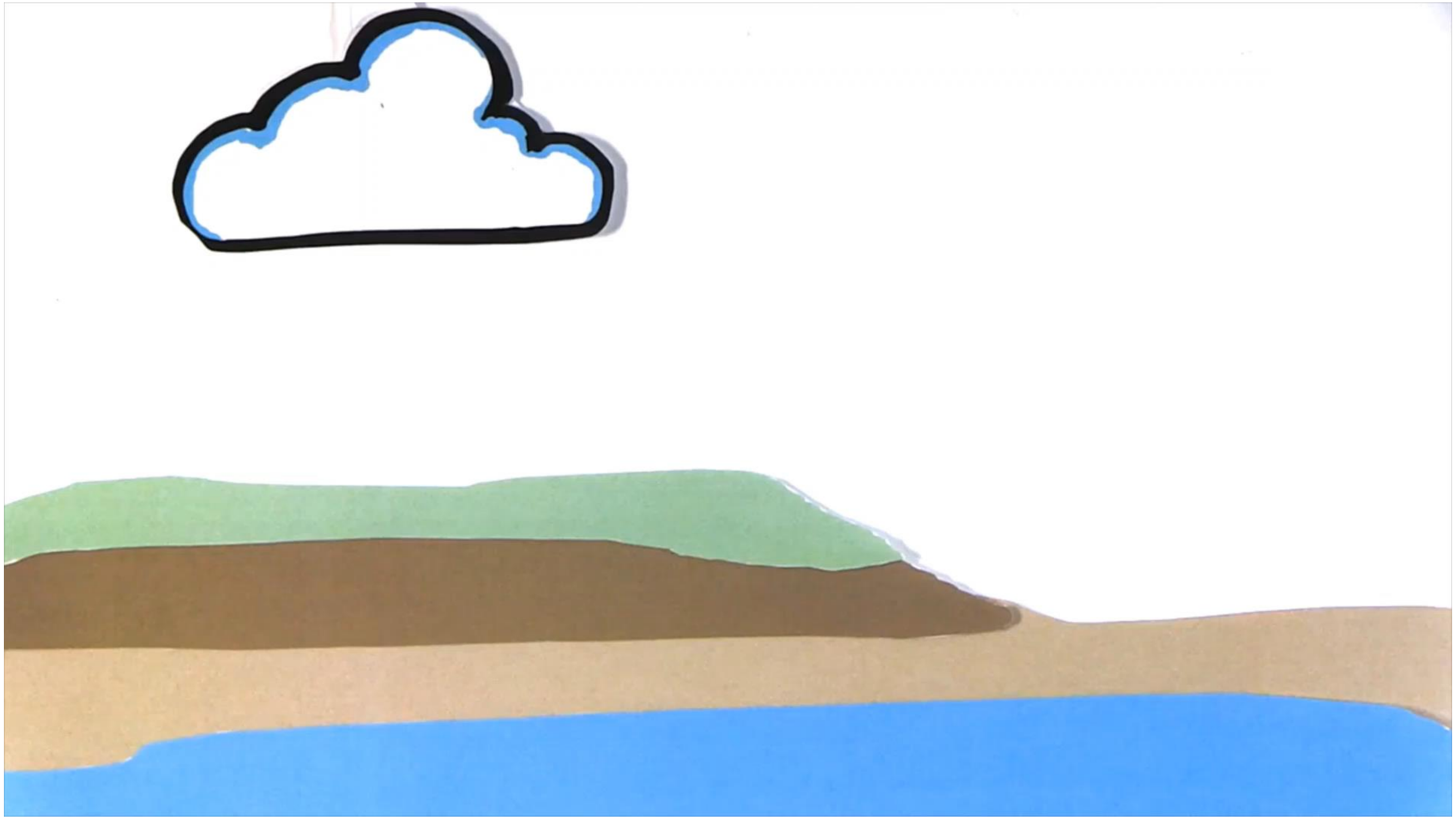


	Нуур	Мөсөн гол	Гол	Газрын доорх ус
Series1	500	62.9	34.6	10.8

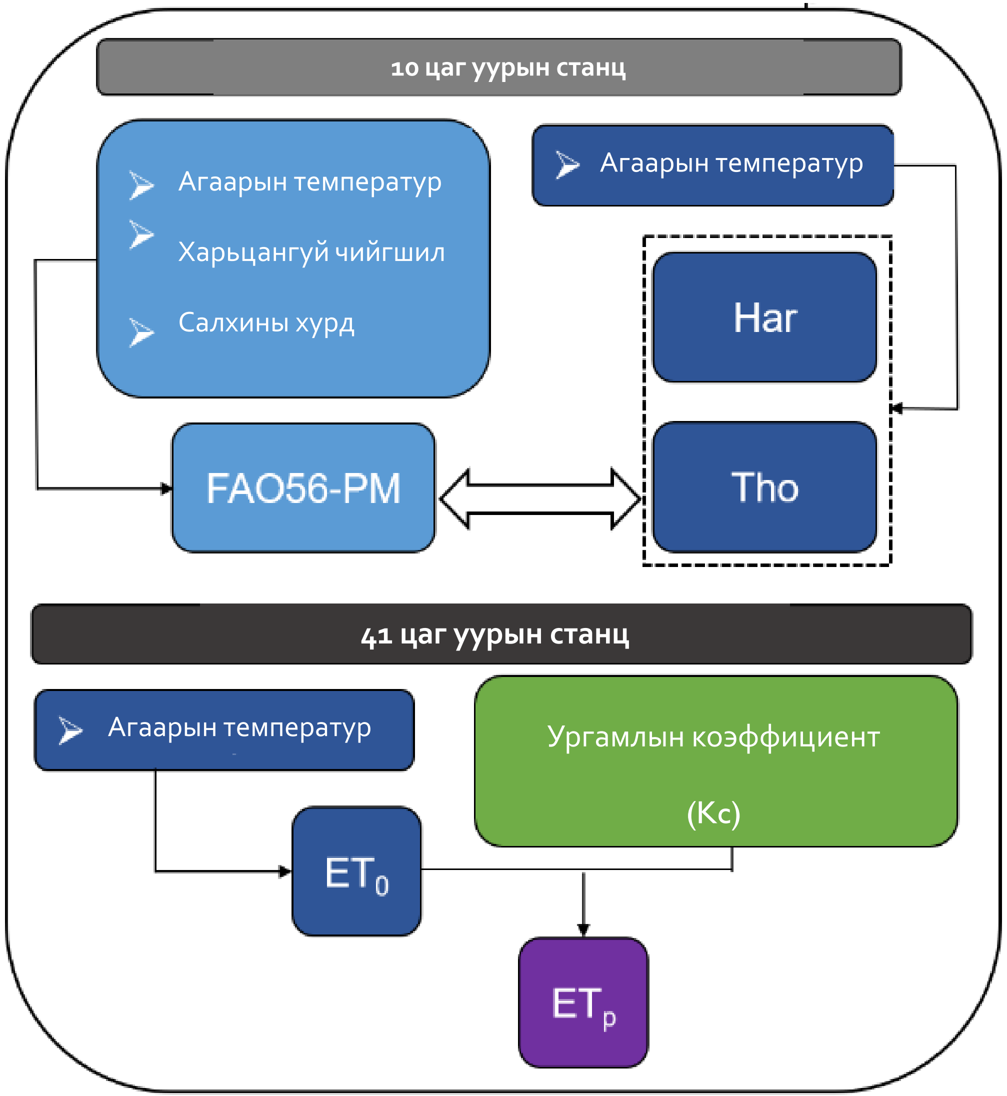
ГАЗРЫН ДООРХ УСНЫ ТЭЖЭЭМЖ ТООЦОХ АРГАЧЛАЛУУД

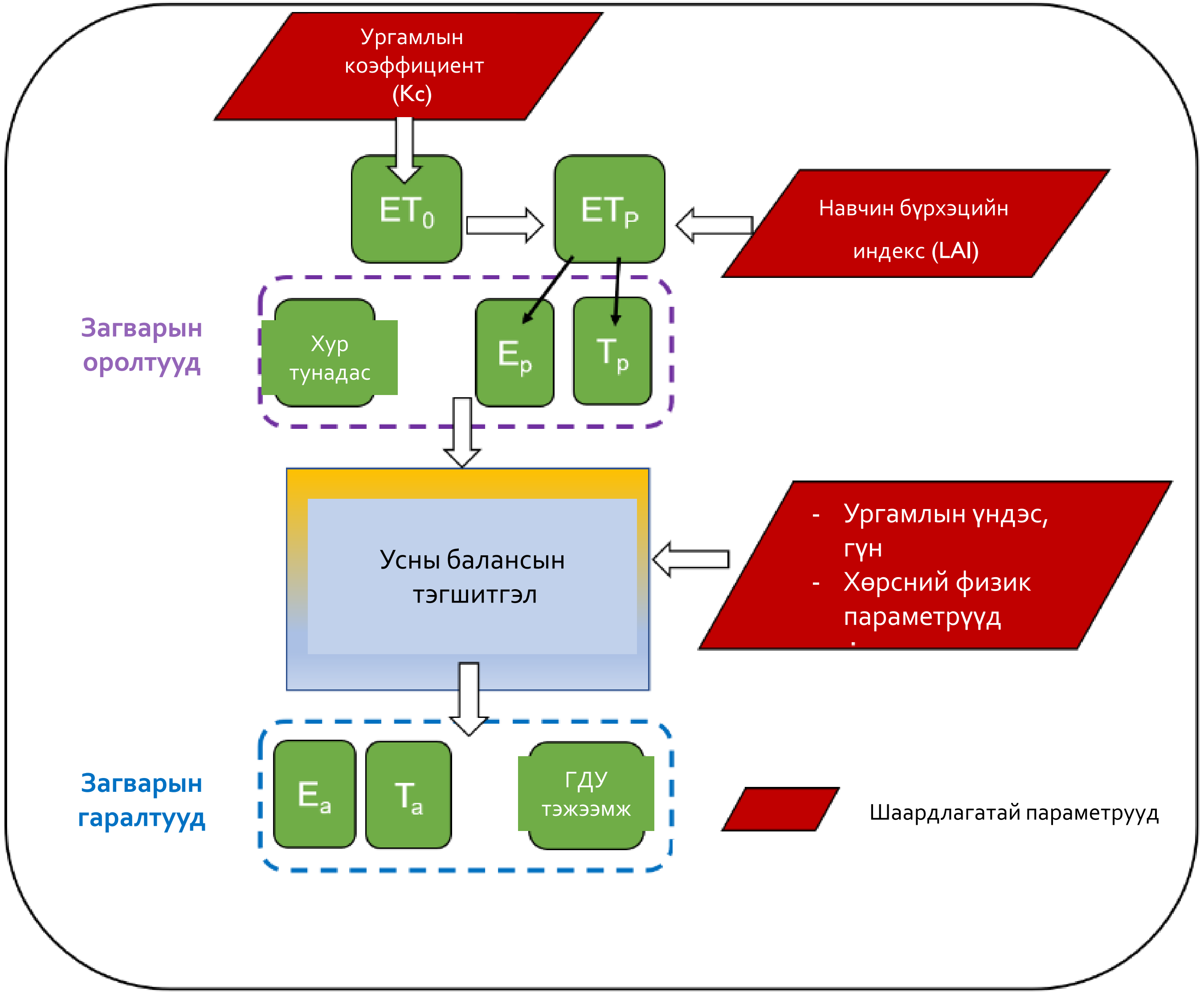
- Усны баланс
- Газар доорх усны загварчлал
- Газрын доорх усны түвшний хэлбэлзэл
- Эмпирик аргачлалууд
- Изотоп
- Лизиметр

ГАЗРЫН ДООРХ УСНЫ ТЭЖЭЭМЖ



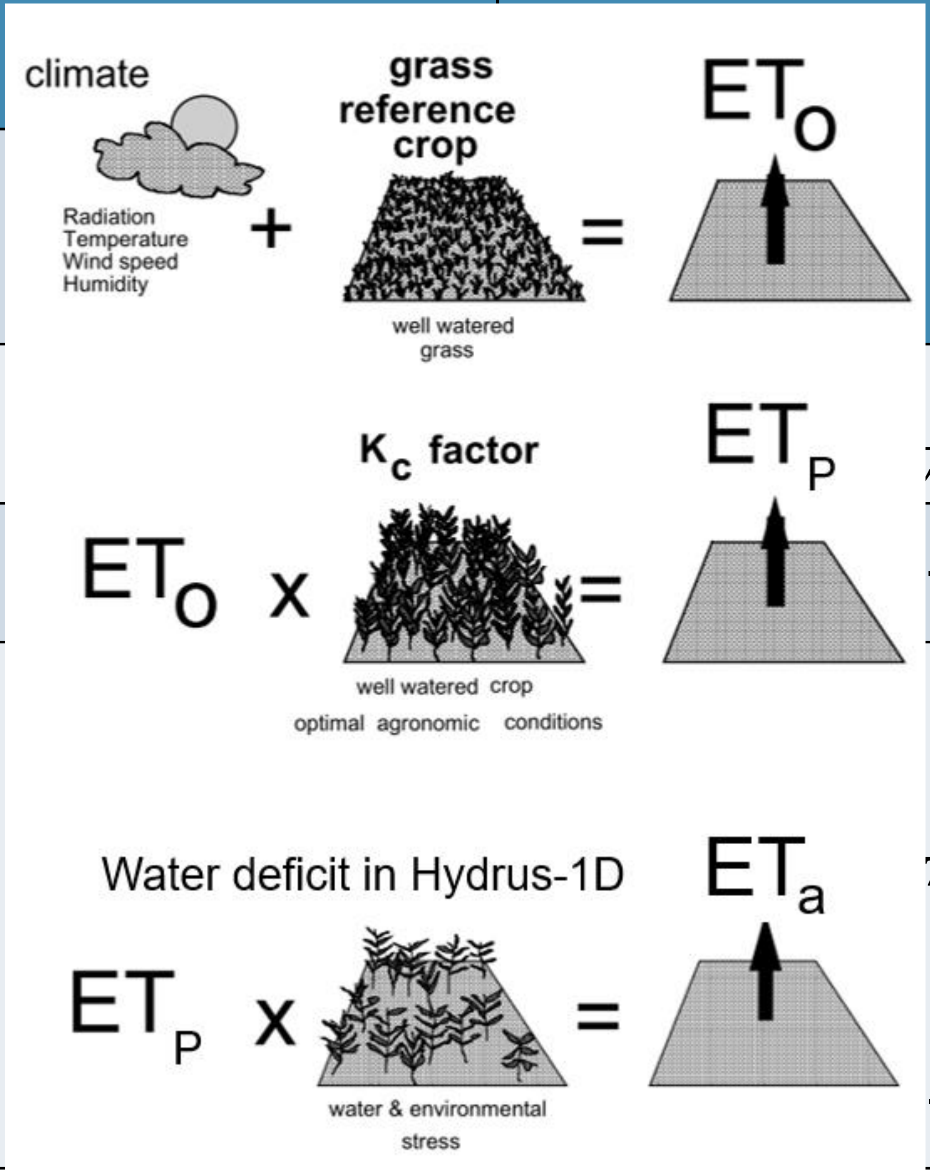
СУДАЛГААНЫ СХЕМ

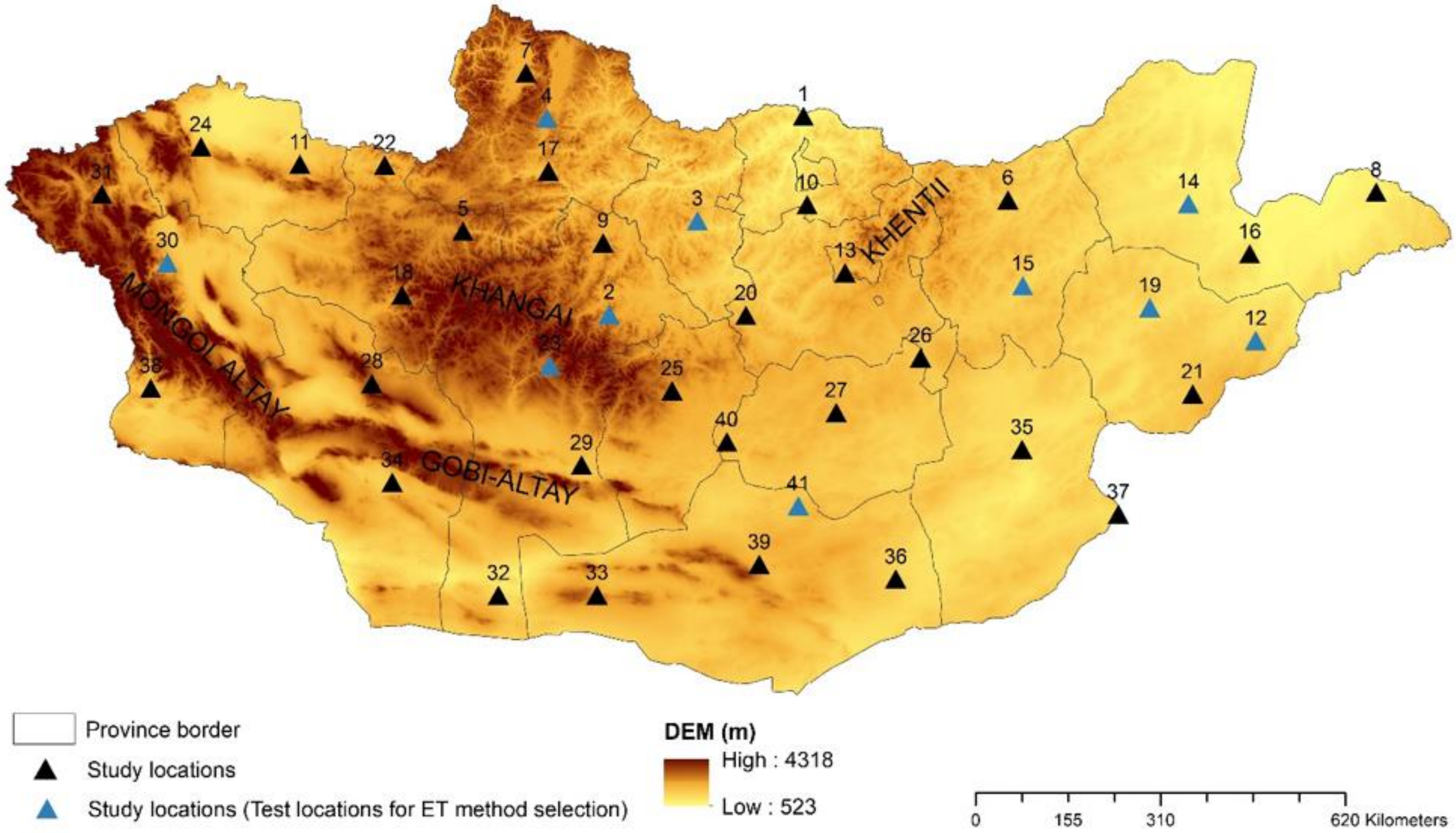




АРГАЧЛАЛ	СУДАЛГААНЫ МАТЕРИАЛ ЦУГЛУУЛАХ	ҮР ДҮН

Аргачлал	Цаг уурын			Томъёо
	Дунд аж. T°	Max T°	Min T°	
FAO-56 PM	+	+	+	$+\gamma\frac{900}{T+273}u_2(e_s-e_a)$ / $(1+0.34u_2)$
Hargreaves	+	+	+	$.8)(T_{max}-T_{min})^{0.5}(0.408R_a)$
Thornthwaite modified	+			$0, T<0°$ $(\frac{10T}{I})^a, 0\le T\le 26.5°$ $75T-0.0144T^2)\frac{h}{12}, T\ge 26.5°$ $.7110^{-5}I^2)+$





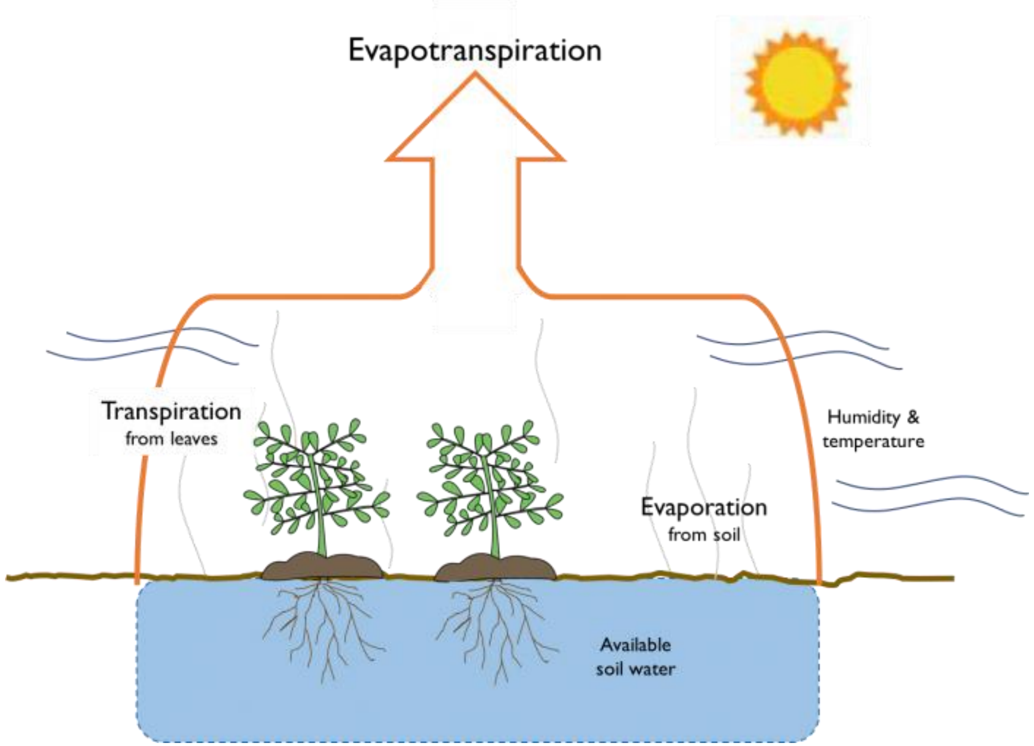
- ET_0 FAO-56 PM (Allen, 1998)
- ET_0 Hargreaves (G. H. Hargreaves & Samani, 1985)
- ET_P Thornthwaite modified (Mintz.Y & Walker.G.K, 1993)

Судалгааны байршил (SRTM) (Earth Resources Observation And Science center, 2017).

$$E_p = ET_p e^{-k*LAI} = ET_p(1 - SCF) = ET_p e^{-0.463LAI}$$

$$T_p = ET_p(1 - e^{-k*LAI}) = ET_p SCF = ET_p - E_p$$

$$AI = \frac{\sum_{i=1}^{5} \frac{P_i}{PET_i}}{5}$$



https://serc.carleton.edu/integrate/teaching_materials/food_supply/student_materials/1091, Beer's law (Ritchie, 1972)

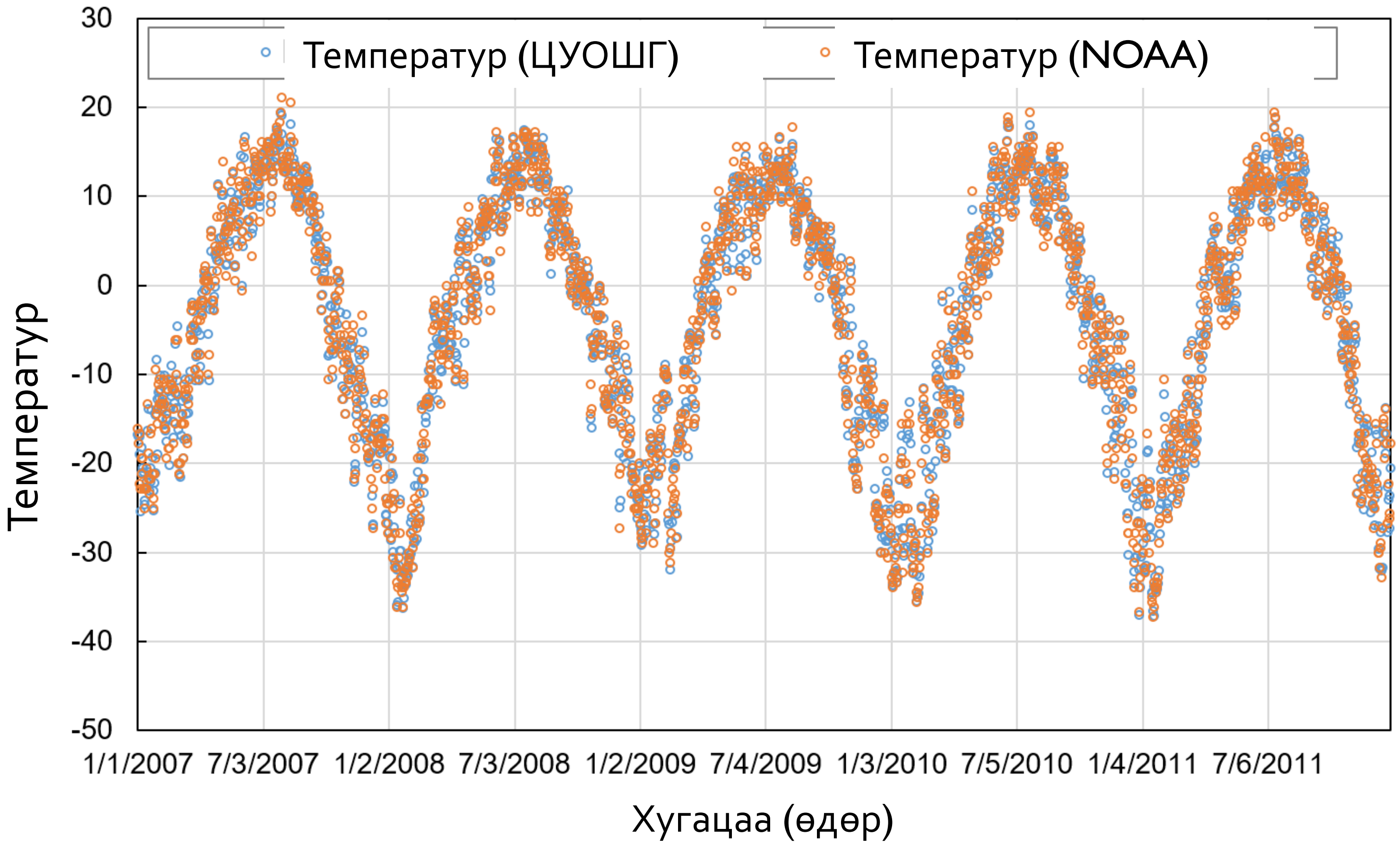
FAO Хуурайшил

Макро анги	Анги	Ангилал
Arid	Desert	AI≤0.03
	Hyper-Arid	0.03<AI≤0.05
	Arid	0.05<AI≤0.2
	Semi-Arid	0.2<AI≤0.5
Mid	Dry	0.5<AI≤0.65
	Sub-humid	0.65<AI≤0.75
Humid	Humid	AI>0.75
Cold	Cold	ET_P≤400 mm

Spinoni et al., 2015. Towards identifying areas at climatological risk of desertification using the Köppen-Geiger classification and FAO aridity index.

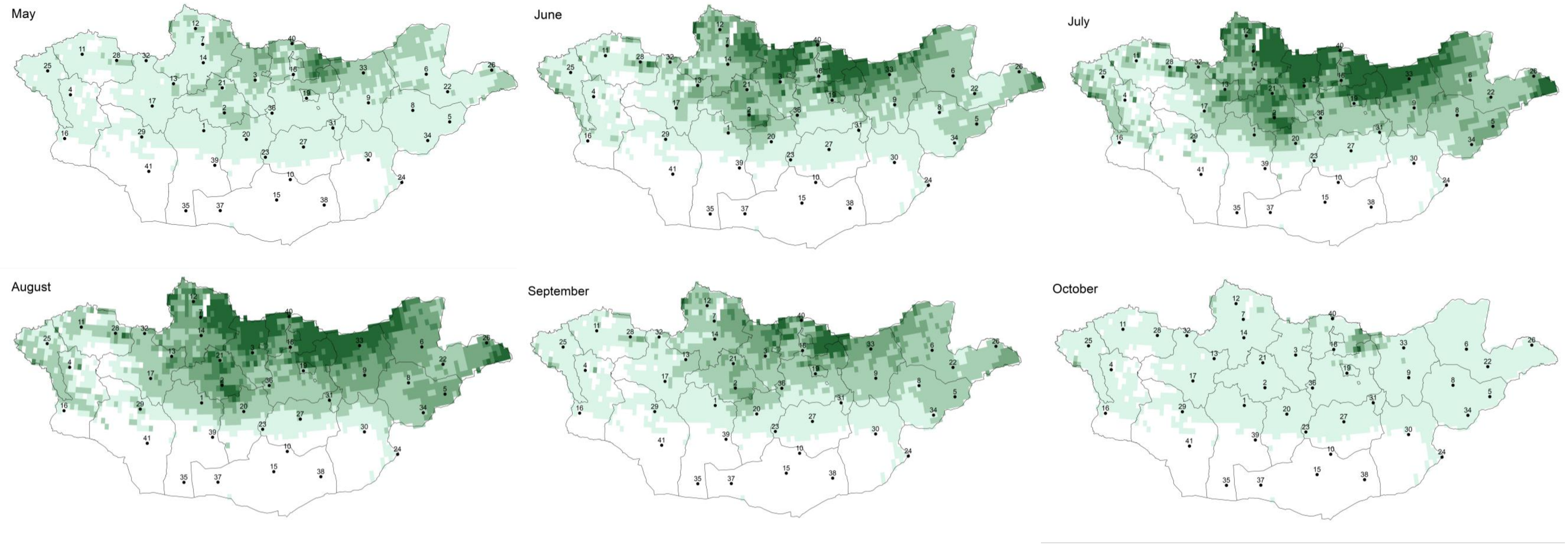
Сар (2015)	NOAA хэмжилт (Cº)	ЦУОШГ хэмжилт (Cº)
1	-20.2	-23.4
2	-20.9	-24.3
3	-4.5	-6.4
4	4.9	4.2
5	9.2	9.1
6	14.7	15.3
7	18.0	19.0
8	15.2	15.9
9	9.9	10.1
10	2.8	2.6
11	-5.8	-7.2
12	-15.3	-18.1

NOAA National Centers for Environmental Information, National Agency Meteorology and the Environmental Monitoring, Mongolia data have been used.

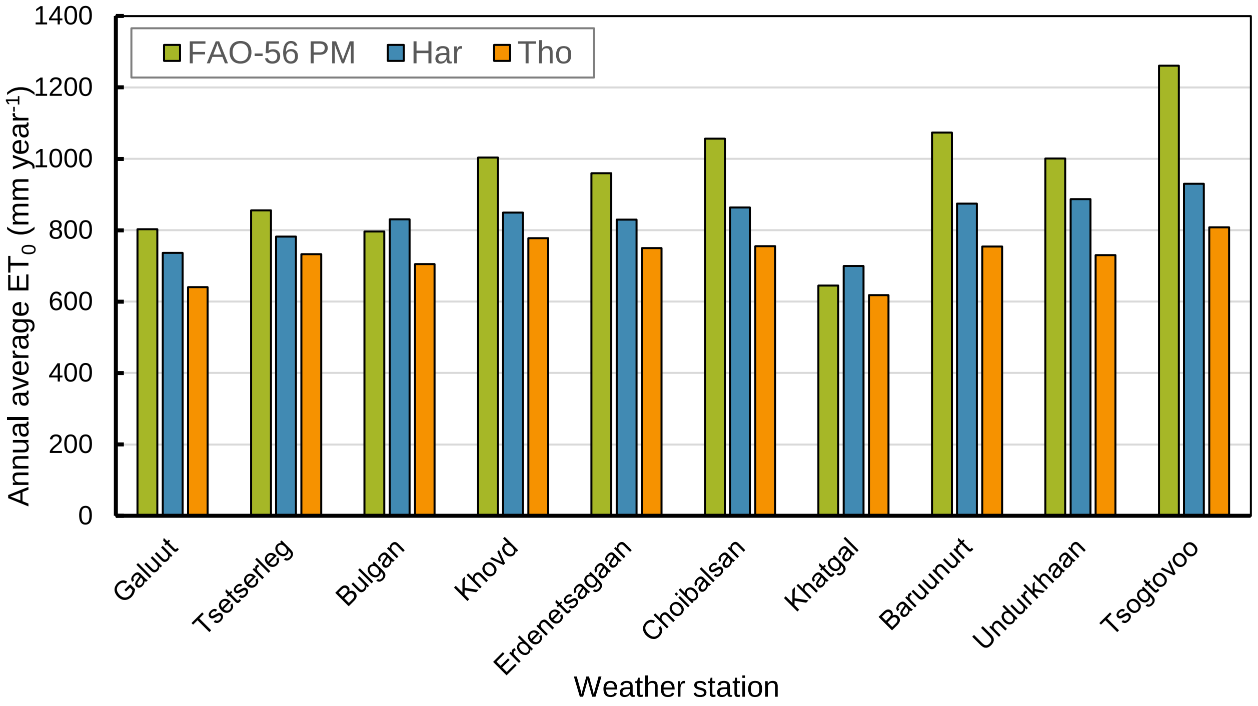


Судалгааны хугацаа: 2007-2011

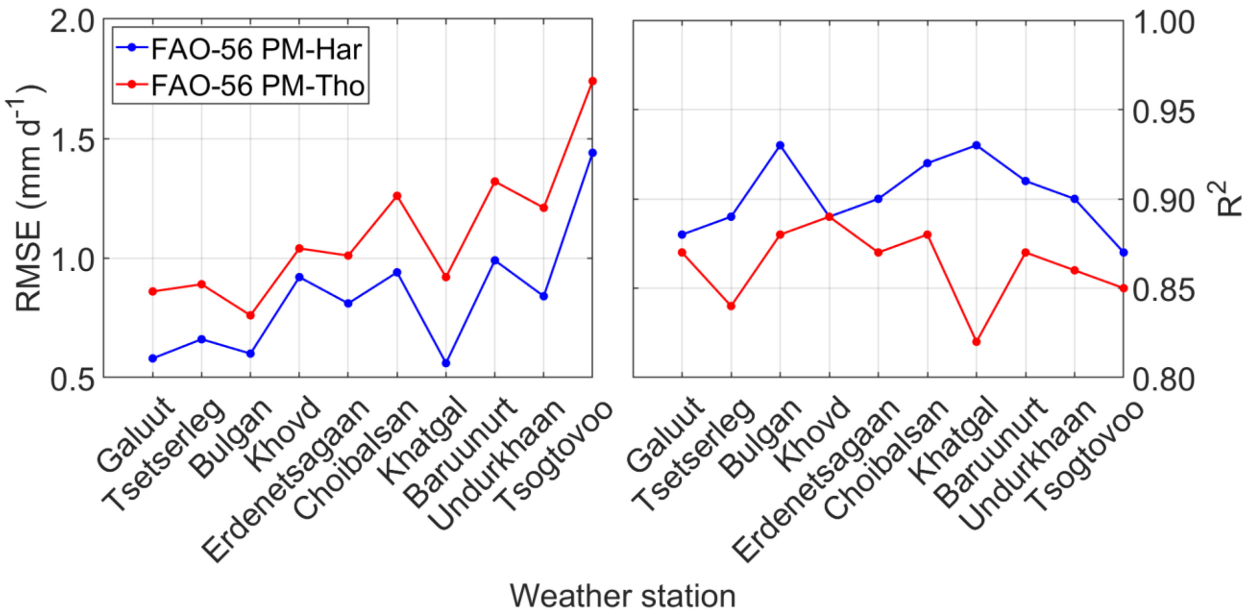
0.25 x 0.25 degree resolution



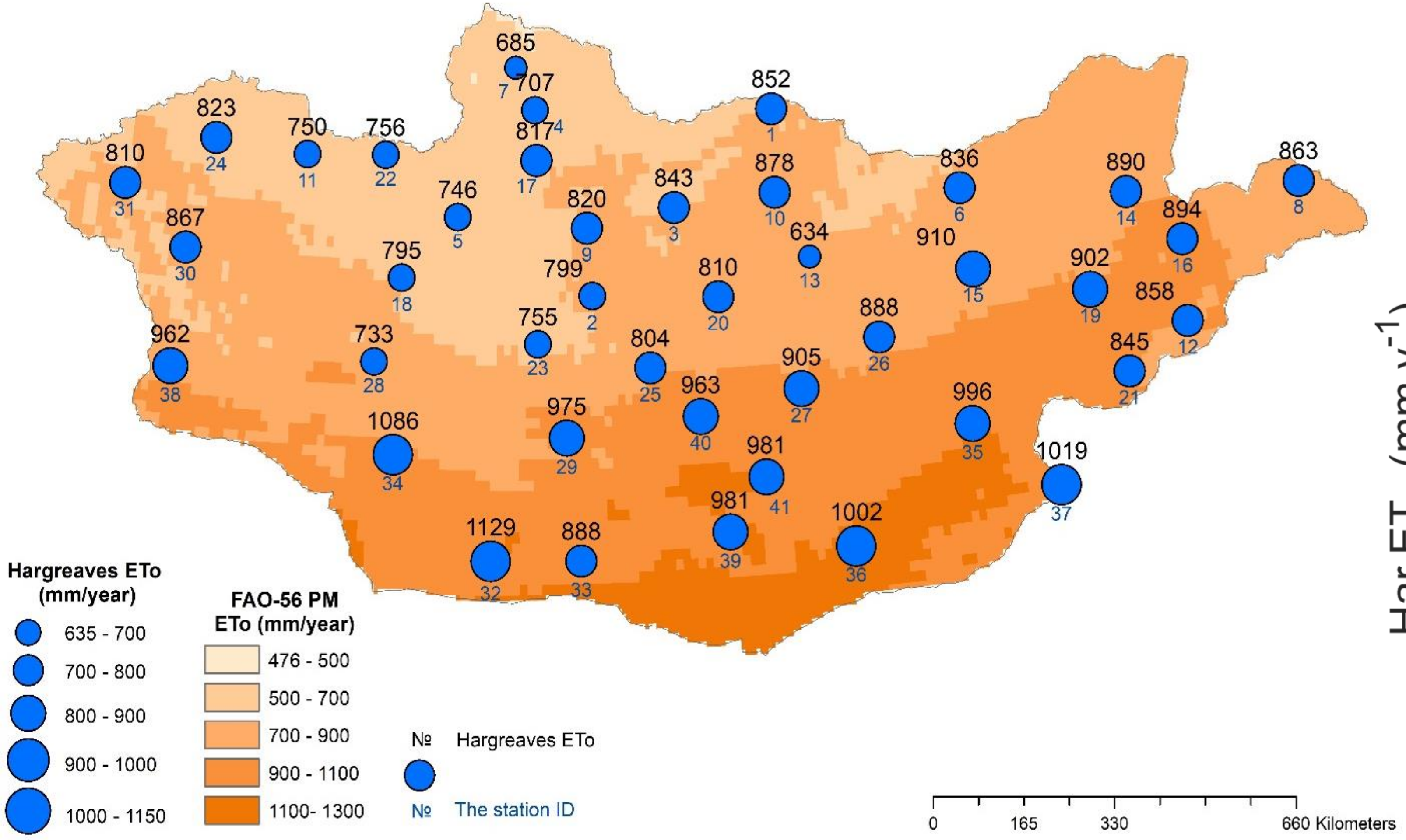
Сарын дундаж ургамлан бүрхэвчийн зураг (*LAI*), (ORNL DAAC Global Monthly mean *LAI)*

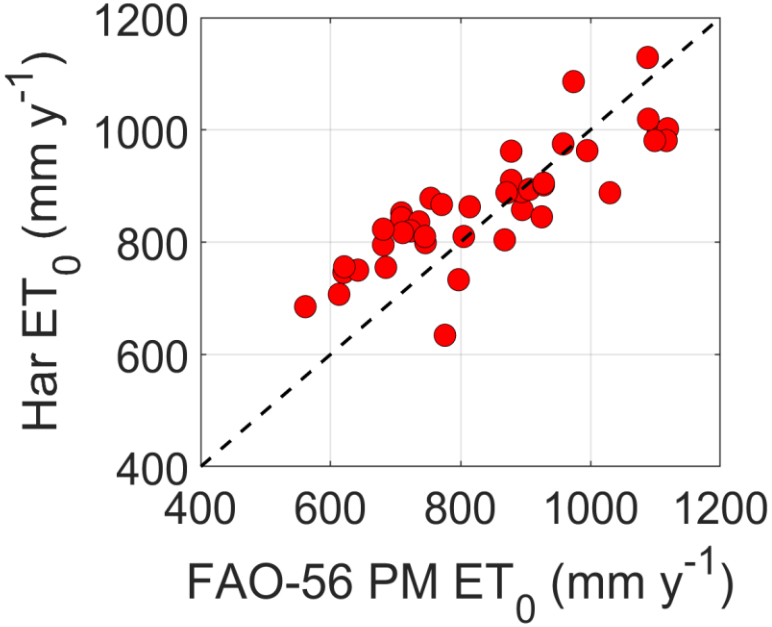


Жилийн дундаж ET_0 (FAO56-PM, Har, Tho)



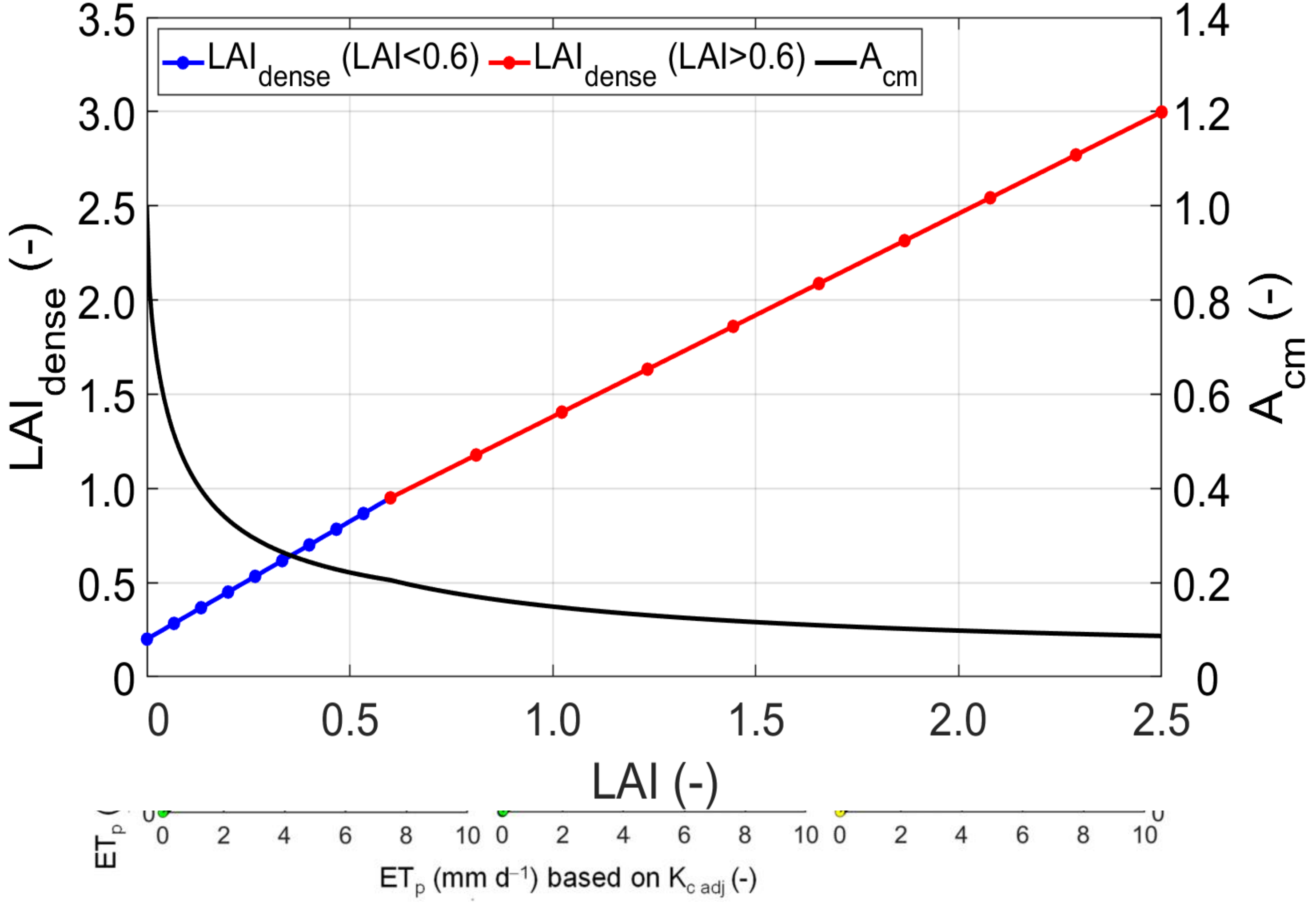
ET_0 тооцоолж буй FAO-56 PM, Har (цэнхэр зураас) болон Tho (улаан зураас) аргачлалуудын холбоо : (a) *RMSE* (mm d^{-1}), (b) R^2 (-)





Hargreaves аргачлалаар тооцсон ET_0 болон FAO (2009) гийн боловсруулсан FAO-56 PM ET_0.

Metadata from FAO. (2009b). Global Map of Yearly Crop Reference Evapotranspiration



Говь

$$K_c = 0.02 * R_n$$

Хээр

$$K_c = \alpha LAI + b$$

$$K_{c\,adj} = K_c - A_{cm}$$

$$A_{cm} = 1 - \left[\frac{LAI}{LAI_{dense}}\right]^{0.5}$$

$$LAI_{dense} = \begin{cases} \frac{0.95 - 0.2}{0.6 - 0} LAI + 0.2, & LAI < 0.6 \\ \frac{3.03 - 0.95}{2.53 - 0.6}(LAI - 0.6) + 0.95, & LAI > 0.6 \end{cases}$$

K_c - ургамлын коэффициент

$K_{c\,adj}$ - тооцсон ургамлын коэффициент

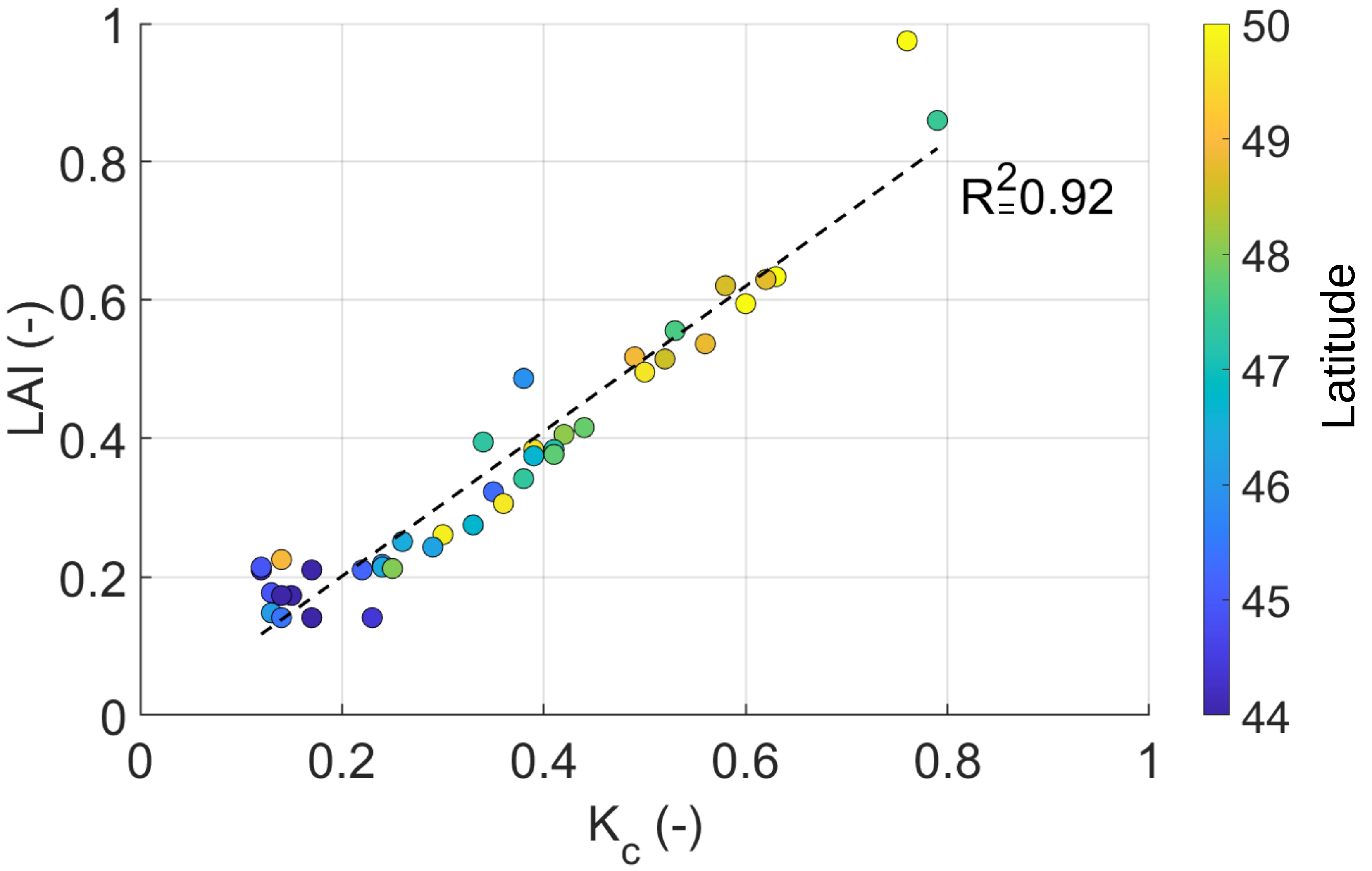
LAI – Навчны индекс

LAI_{dense} = LAI навчны индекс (ургамал стрессгүй байх үед)

R_n - Нийт нарны цацраг

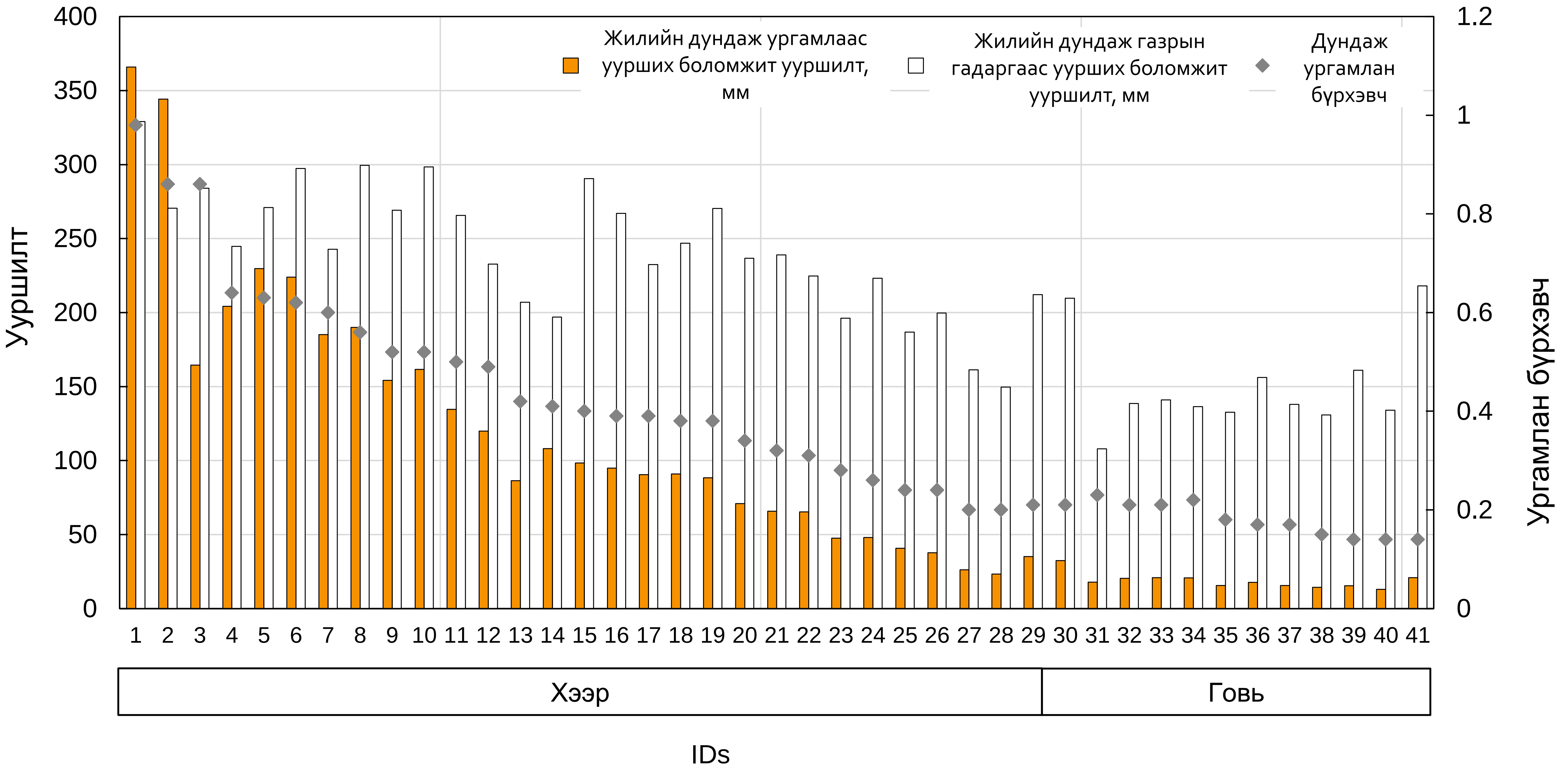
https://www.eic.mn:8443/geonetwork

АРГАЧЛАЛ	СУДАЛГААНЫ МАТЕРИАЛ ЦУГЛУУЛАХ	ҮР ДҮН



Шинээр зохиосон ургамлын коэфициент болон өргөрөг, навчны индексийн холбоо

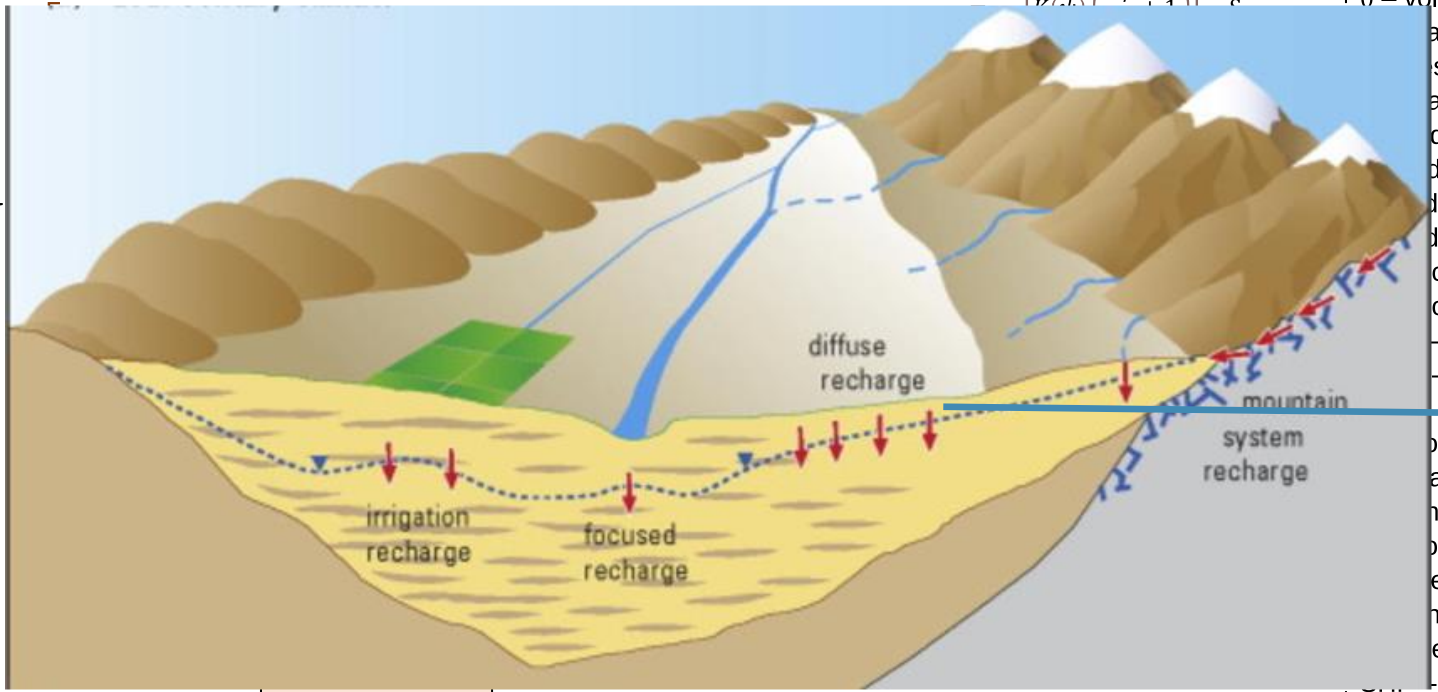
АРГАЧЛАЛ	СУДАЛГААНЫ МАТЕРИАЛ ЦУГЛУУЛАХ	ҮР ДҮН

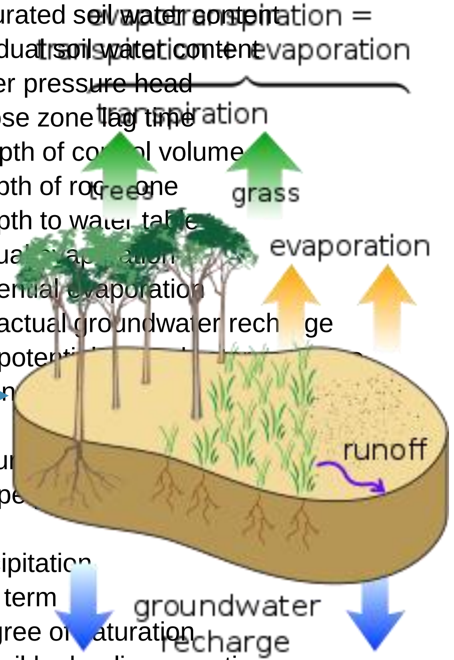


Боломжит ууршилтын хэмжээ, судалгааны цэгүүдээр

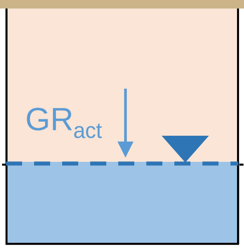
Загварт шаардлагатай параметрүүд	Үр дүн	Үндсэн тэгшитгэл, аргачлал	Товчилсон үгс
P			

Усаар ханаагүй бүс



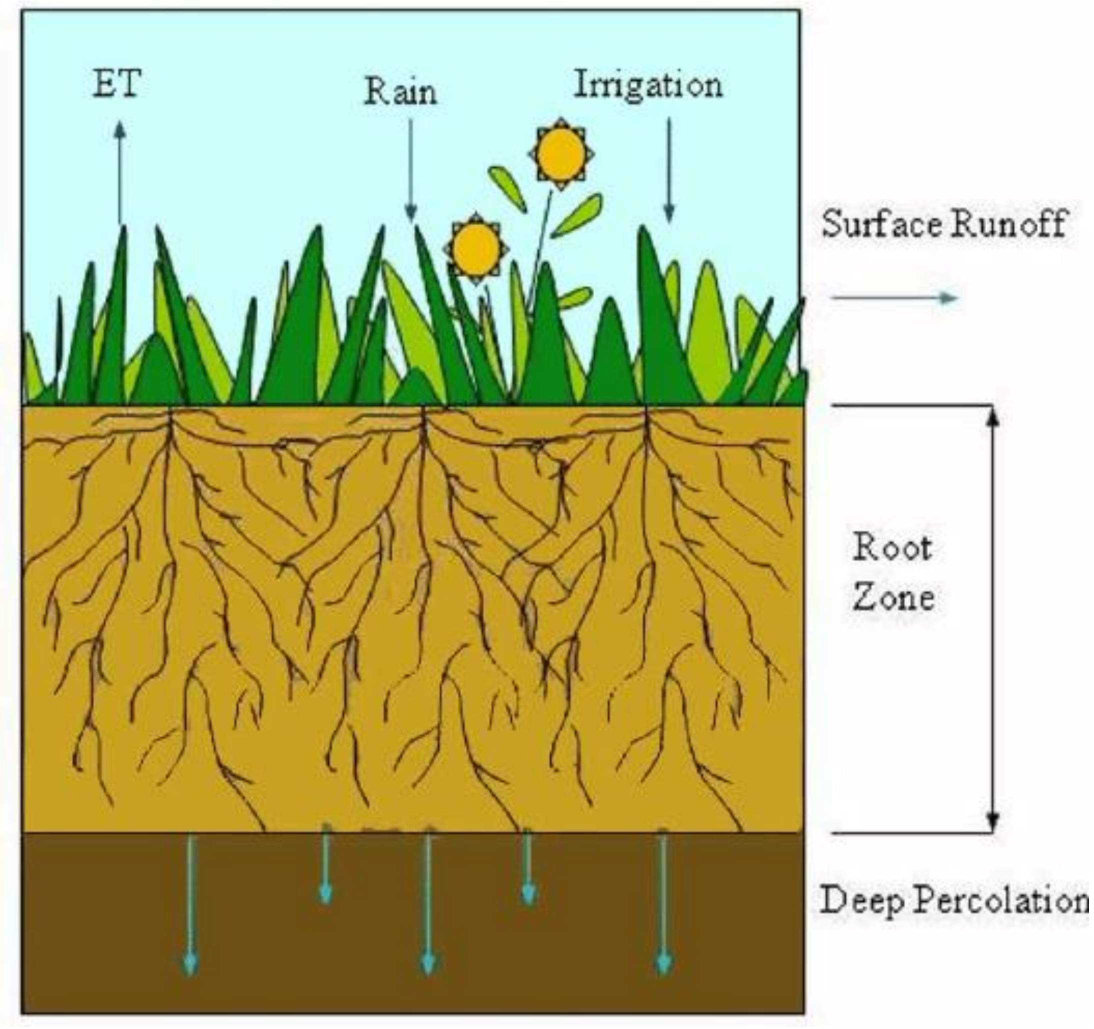


c – soil moisture vertical velocity
θ – volumetric soil water content
...aturated soil water content
...sidual soil water content
...ater pressure head
...dose zone lag time
...depth of co...l volume
...depth of ro... one
...depth to wat... table
...ctual ...
...otential evaporation
... – actual groundwater rech... ge
... – potent...
...on
...atur...
...ape...
...on
...ecipitation
...nk term
...egree of saturation
... – soil hydraulic properties
SPP – soil physical properties
T_a – actual transpiration
T_p – potential evapotranspiration
z – vertical coordinate

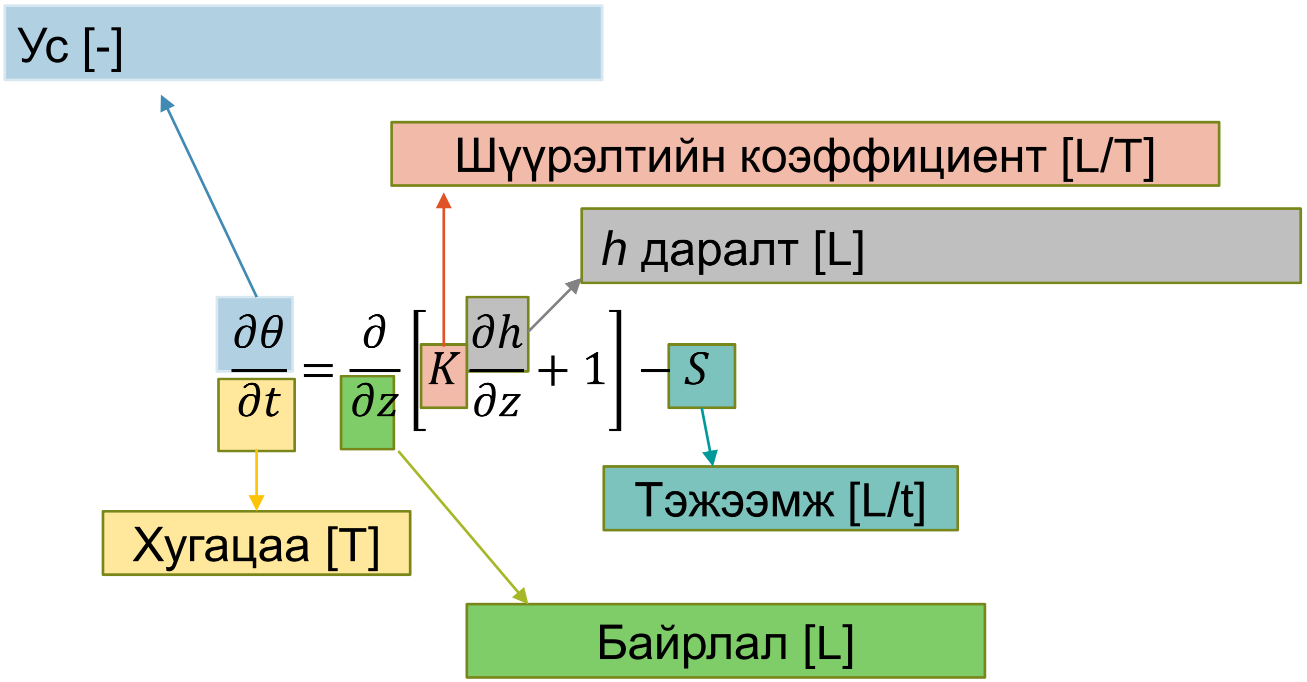


$D_{wt\ (site\ dependent)}$

Газрын доорх усны түвшин



(Dukes et al., 2009. Smart Irrigation Controllers : Operation of Evapotranspiration-Based Controllers)



$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z}\left[K\frac{\partial h}{\partial z} + 1\right] - S$$

The sink term, S, is defined as the volume of water removed from a unit volume/depth of soil per unit time due to the plant water uptake (Šimunek, 2015).

Хур тунадасны алдагдал

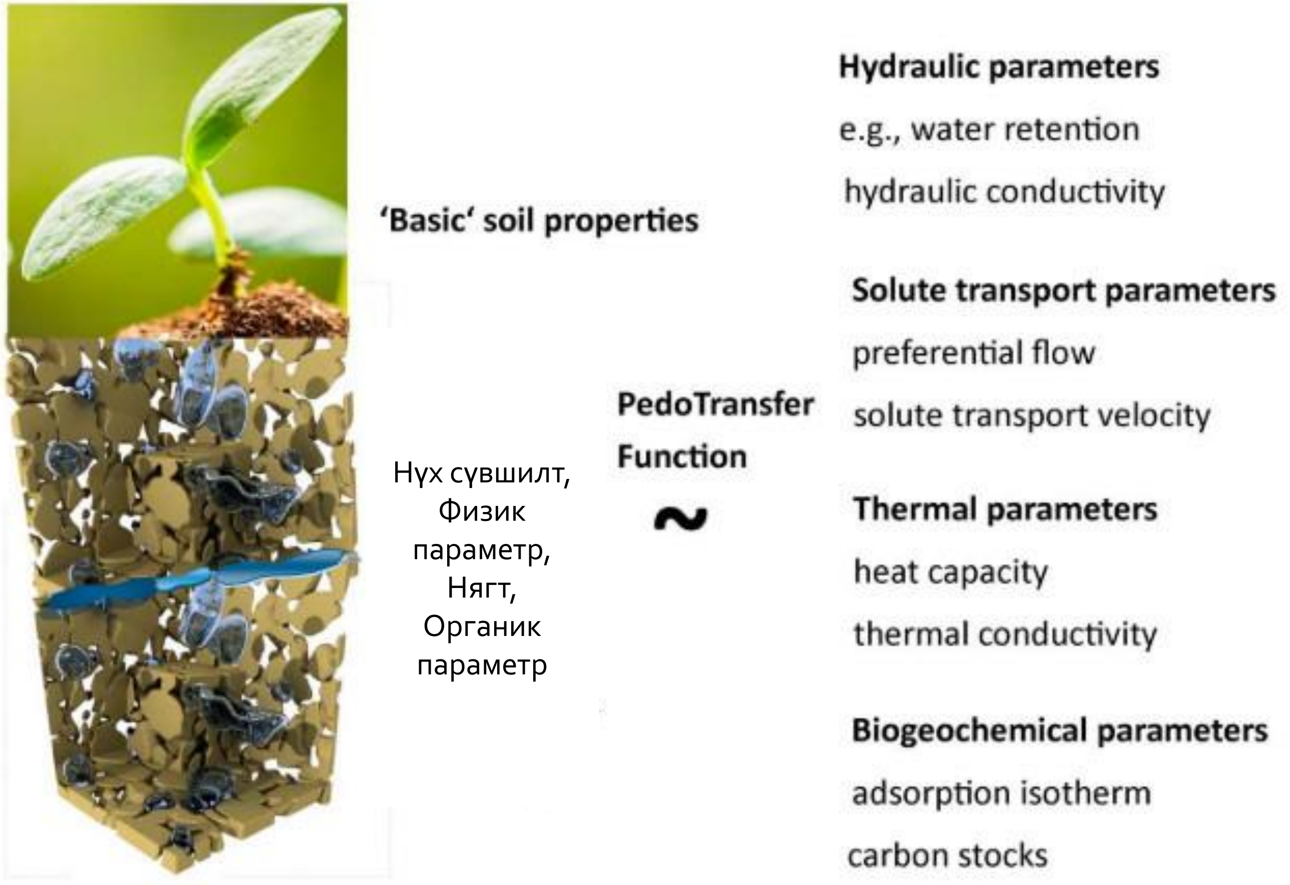
Навчны индекс

$$RI = a\,LAI\left(1 - \frac{1}{1+\frac{bP}{aLAI}}\right)$$

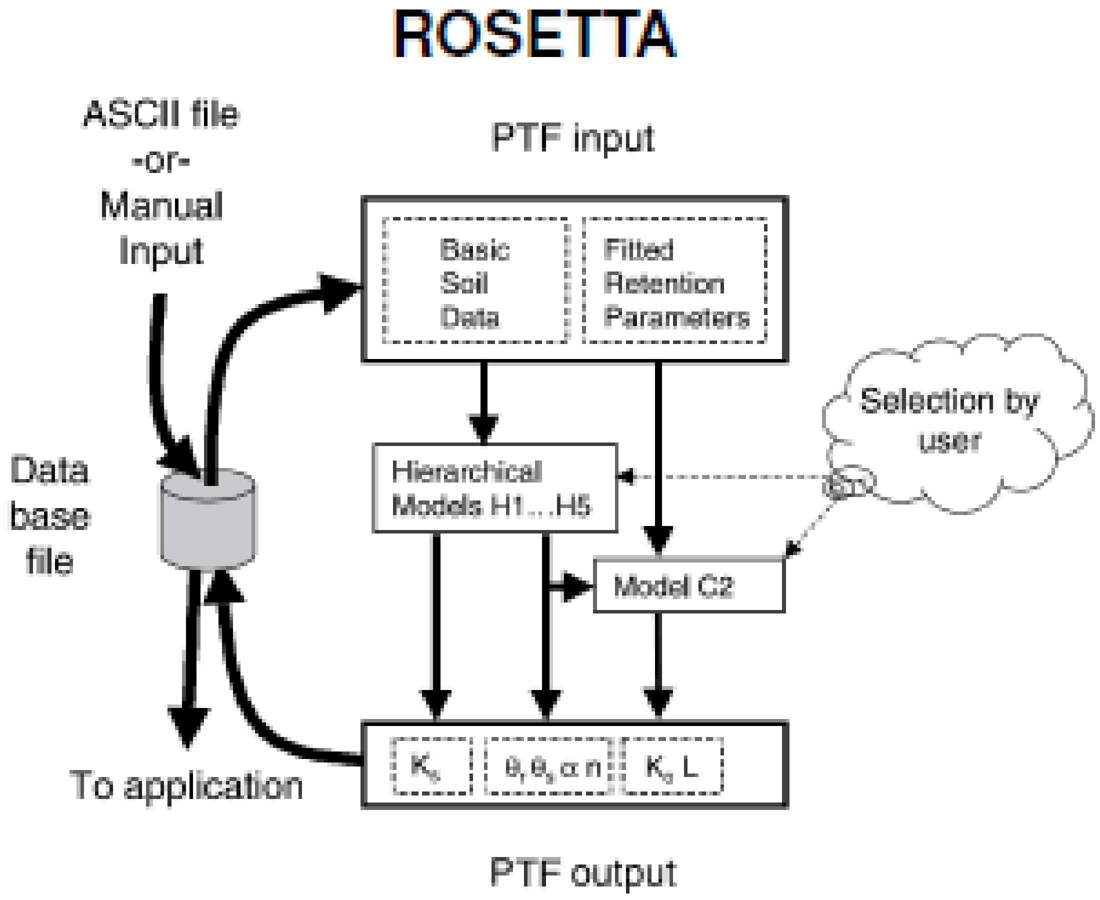
Эмпирик коэффициент, 0.025 см/өдөр

b (-) хөрсний харьцаа: $b = 1 - e^{-kLAI}$

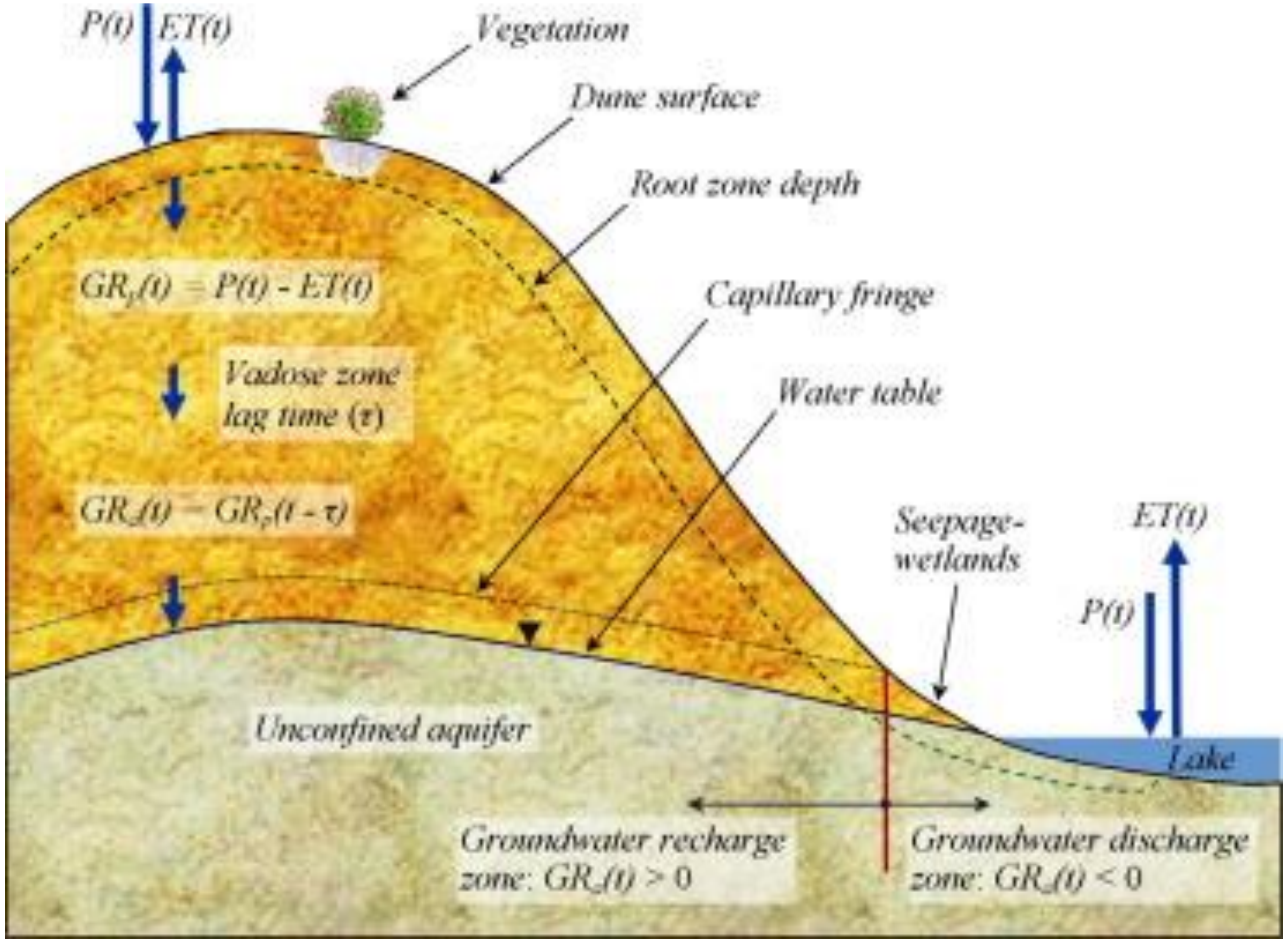
Nasta, P., & Gates, J. B. (2013). Plot-scale modeling of soil water dynamics and impacts of drought conditions beneath rainfed maize in Eastern Nebraska



Нүх сүвшилт,
Физик параметр,
Нягт,
Органик параметр



Van Looy et al. (2017), Pedotransfer Functions in Earth System Science: Challenges and Perspectives



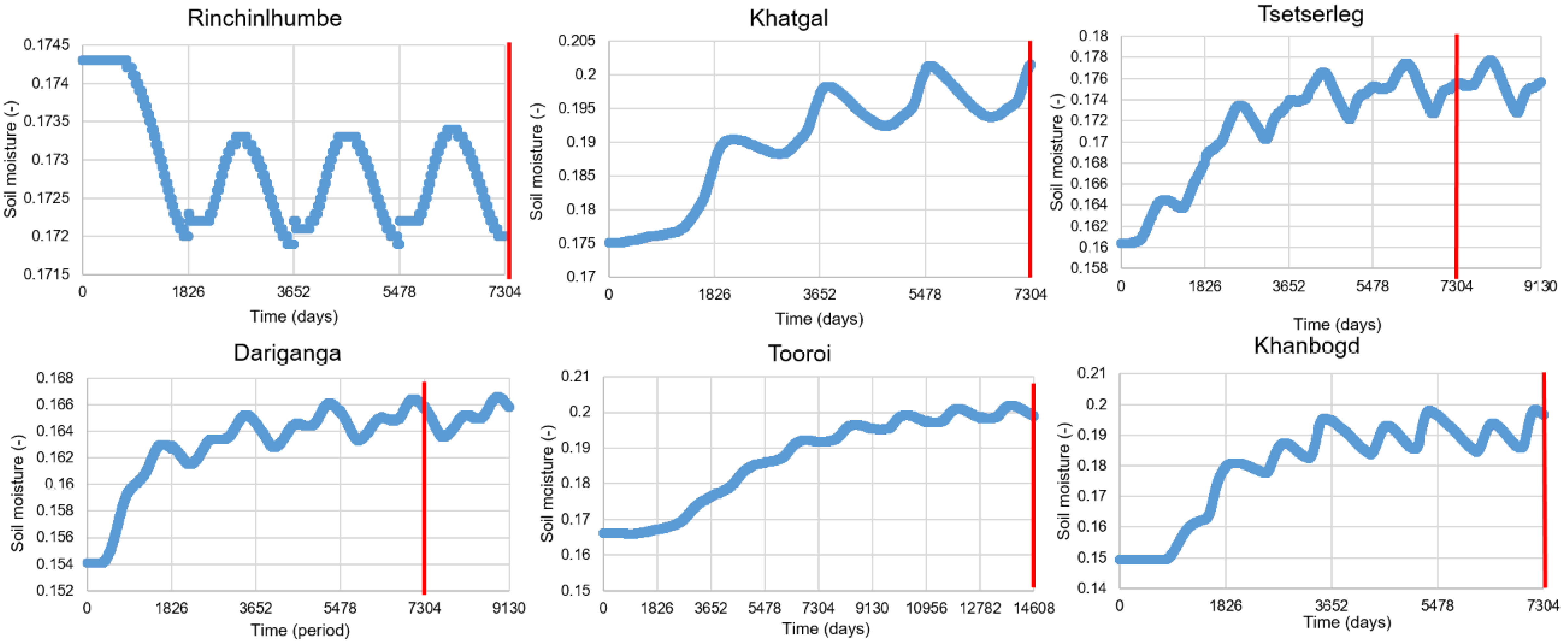
$\tau = D_{wt}/c$

c (хурд)

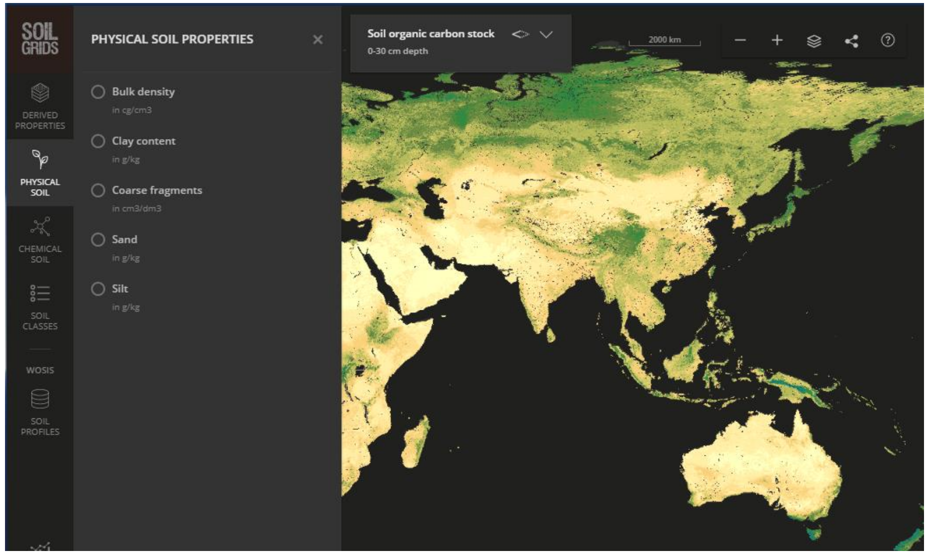
D_{wt} ГДУ түвшин

τ ГДУ-нд хүрэх хугацаа

Rossman et al., 2014. Vadose zone lag time and potential 21st century climate change effects on spatially distributed groundwater recharge in the semi-arid Nebraska Sand Hills.


Rinchinlhumbe
Soil moisture (-)
0.1745
0.174
0.1735
0.173
0.1725
0.172
0.1715
0
1826
3652
5478
7304
Time (days)
Khatgal
Soil moisture (-)
0.205
0.2
0.195
0.19
0.185
0.18
0.175
0.17
0
1826
3652
5478
7304
Time (days)
Tsetserleg
Soil moisture (-)
0.18
0.178
0.176
0.174
0.172
0.17
0.168
0.166
0.164
0.162
0.16
0.158
0
1826
3652
5478
7304
9130
Time (days)
Dariganga
Soil moisture (-)
0.168
0.166
0.164
0.162
0.16
0.158
0.156
0.154
0.152
0
1826
3652
5478
7304
9130
Time (period)
Tooroi
Soil moisture (-)
0.21
0.2
0.19
0.18
0.17
0.16
0.15
0
1826
3652
5478
7304
9130
10956
12782
14608
Time (days)
Khanbogd
Soil moisture (-)
0.21
0.2
0.19
0.18
0.17
0.16
0.15
0.14
0
1826
3652
5478
7304
Time (days)

HYDRUS-1D



ISRIC – SoilGrids
World Soil Information (van den Bosch & Batjes, N, 2013)

Texture	Ks (cm/days)
Sand	712.8
Loamy sand	350.2
Sandy loam	106.1
Loam	24.96
Silt	6
Silt loam	10.8
Sandy clay loam	31.44
Clay loam	6.24
Silty clay loam	1.68
Sandy clay	2.88
Silty clay	0.48
Clay loam	4.8

Талбай	Гүн	Шавар (%)	Тоосонцор (%)	Элс (%)	Нягт (g/cm3)
1	0-5 cm	21.52	37.74	40.74	1.17
	5-15 cm	20.50	38.10	41.40	1.25
	15-30 cm	21.00	37.70	41.30	1.30
	30-60 cm	19.60	38.20	42.20	1.42
	60-100 cm	19.20	38.40	42.40	1.47
	100-200 cm	20.40	36.90	42.70	1.48

Qr	Qs	Alpha (1/cm)	n	Ks (cm/days)	l
0.0703	0.464	0.0087	1.5438	38.93	0.5
0.0672	0.4419	0.0089	1.5367	26.55	0.5
0.0662	0.4301	0.0093	1.5346	20.75	0.5
0.0605	0.3985	0.0104	1.5096	13.53	0.5
0.0583	0.3863	0.011	1.4913	11.46	0.5
0.0602	0.3883	0.0116	1.4763	10.5	0.5

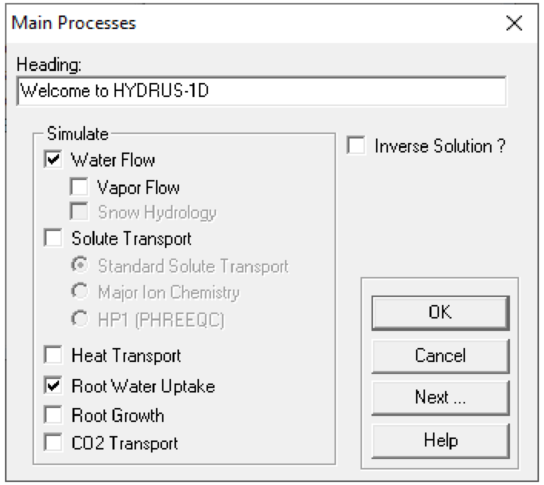
Ургамлын үндэсний гүн – 97 cm Заг (*Haloxylon ammodendron*)

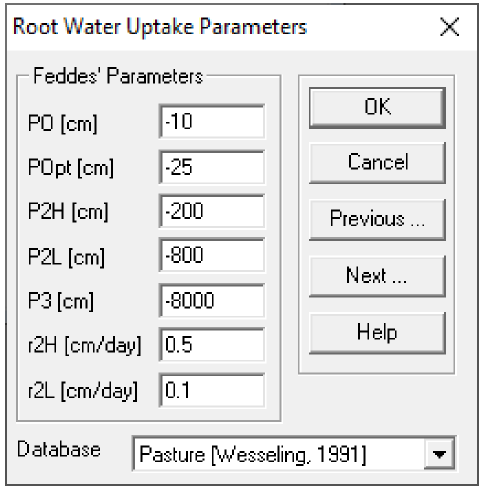
Ургамлын үндэсний гүн – 30 см бусад ургамалд

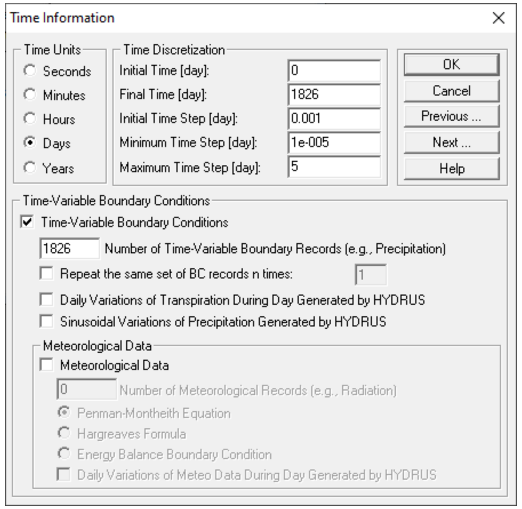
Хур тунадас – ЦУОШГ

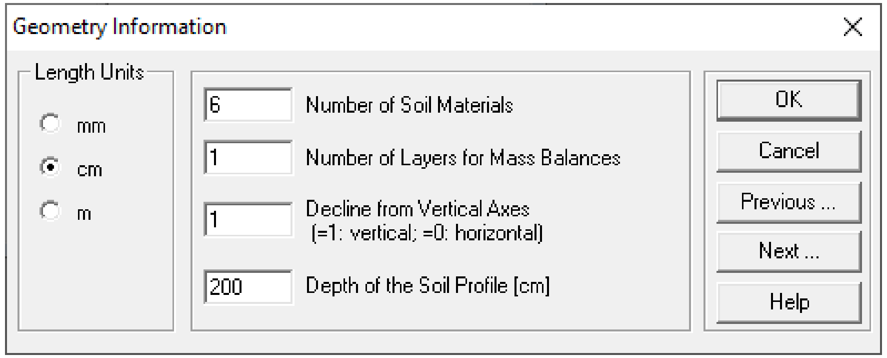
Ууршилт – Судалгааны хүрээнд тооцсон

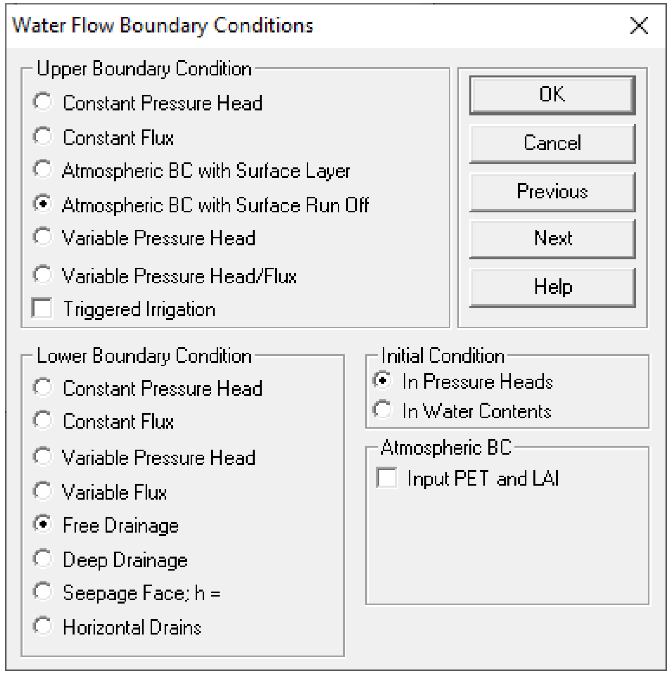
Газрын доорх усны түвшин – гидрогеологийн зураг

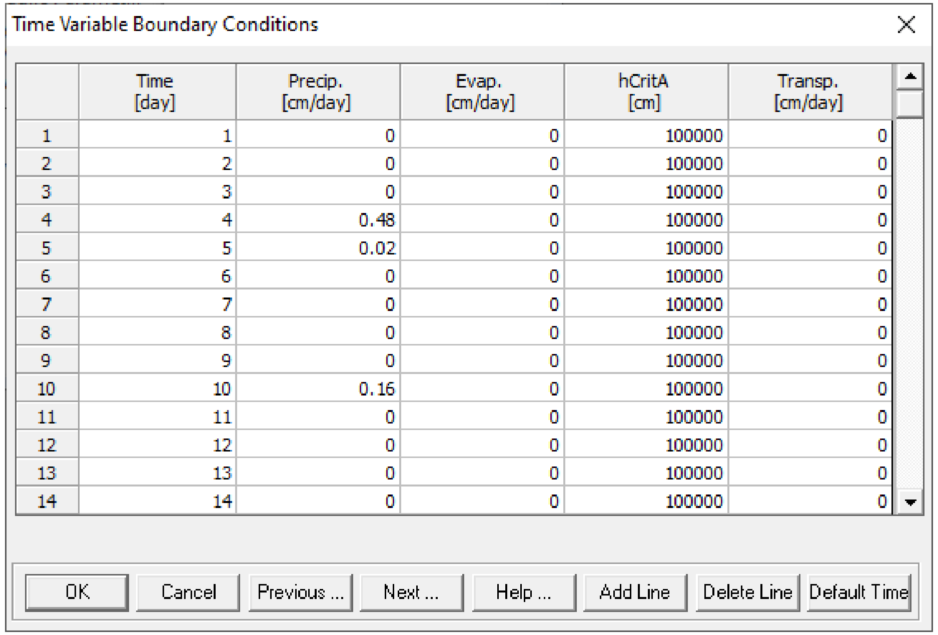

Main Processes
Heading:
Welcome to HYDRUS-1D
Simulate
Water Flow
Vapor Flow
Snow Hydrology
Solute Transport
Standard Solute Transport
Major Ion Chemistry
HP1 (PHREEQC)
Heat Transport
Root Water Uptake
Root Growth
CO2 Transport
Inverse Solution ?
OK
Cancel
Next ...
Help

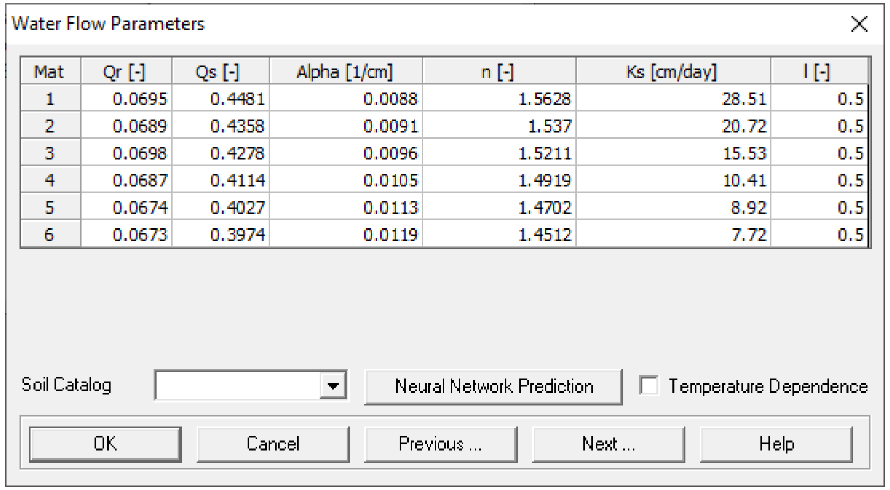

Root Water Uptake Parameters
Feddes' Parameters
P0 [cm] -10
POpt [cm] -25
P2H [cm] -200
P2L [cm] -800
P3 [cm] -8000
r2H [cm/day] 0.5
r2L [cm/day] 0.1
OK
Cancel
Previous ...
Next ...
Help
Database
Pasture [Wesseling, 1991]


Time Information
Time Units
Seconds
Minutes
Hours
Days
Years
Time Discretization
Initial Time [day]: 0
Final Time [day]: 1826
Initial Time Step [day]: 0.001
Minimum Time Step [day]: 1e-005
Maximum Time Step [day]: 5
OK
Cancel
Previous ...
Next ...
Help
Time-Variable Boundary Conditions
Time-Variable Boundary Conditions
1826 Number of Time-Variable Boundary Records (e.g., Precipitation)
Repeat the same set of BC records n times: 1
Daily Variations of Transpiration During Day Generated by HYDRUS
Sinusoidal Variations of Precipitation Generated by HYDRUS
Meteorological Data
Meteorological Data
0 Number of Meteorological Records (e.g., Radiation)
Penman-Montheith Equation
Hargreaves Formula
Energy Balance Boundary Condition
Daily Variations of Meteo Data During Day Generated by HYDRUS

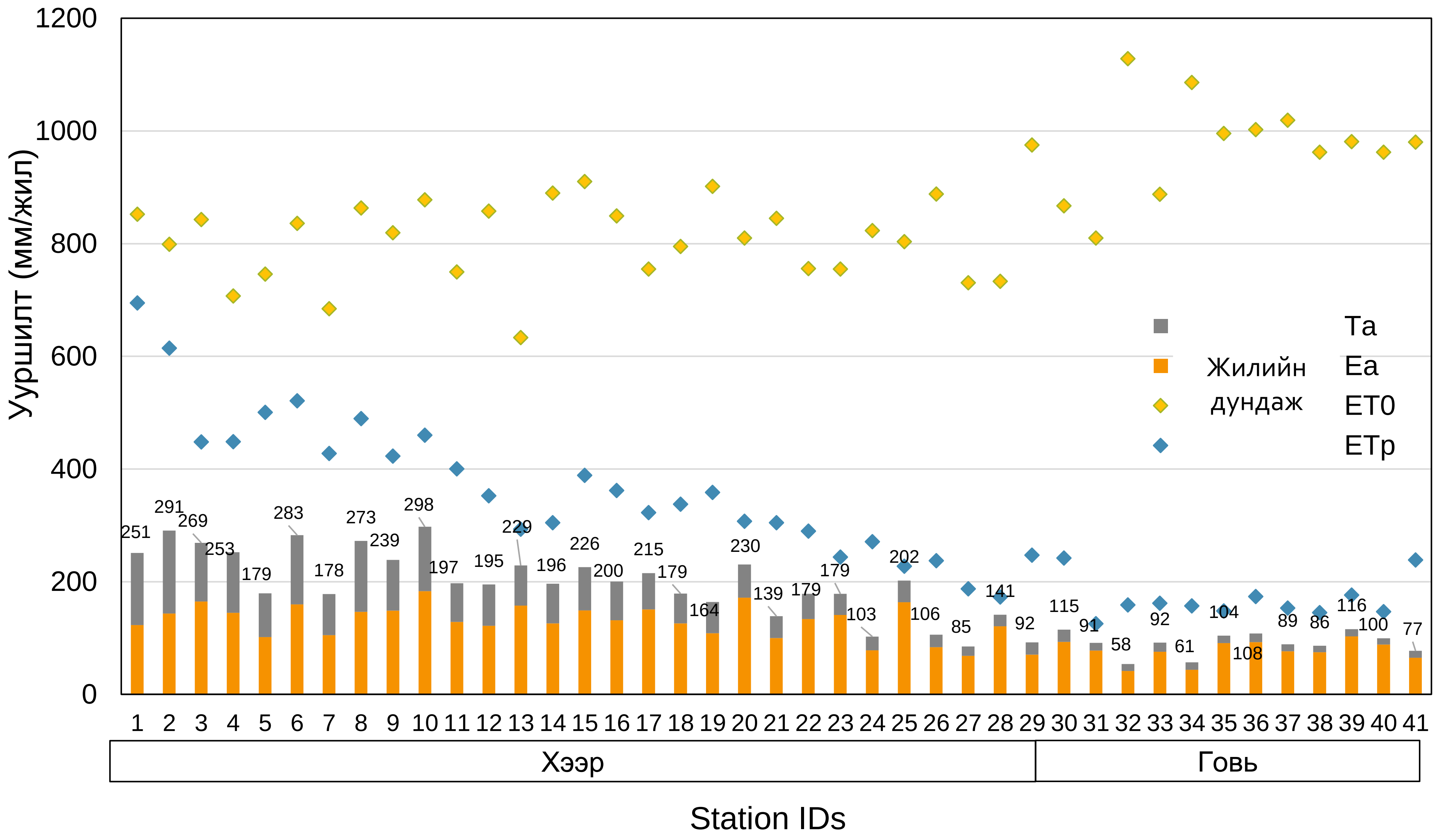

Geometry Information
Length Units
mm
cm
m
6 Number of Soil Materials
1 Number of Layers for Mass Balances
1 Decline from Vertical Axes
(=1: vertical; =0: horizontal)
200 Depth of the Soil Profile [cm]
OK
Cancel
Previous ...
Next ...
Help


Water Flow Boundary Conditions
Upper Boundary Condition
Constant Pressure Head
Constant Flux
Atmospheric BC with Surface Layer
Atmospheric BC with Surface Run Off
Variable Pressure Head
Variable Pressure Head/Flux
Triggered Irrigation
OK
Cancel
Previous
Next
Help
Lower Boundary Condition
Constant Pressure Head
Constant Flux
Variable Pressure Head
Variable Flux
Free Drainage
Deep Drainage
Seepage Face; h =
Horizontal Drains
Initial Condition
In Pressure Heads
In Water Contents
Atmospheric BC
Input PET and LAI


Time Variable Boundary Conditions
Time [day] | Precip. [cm/day] | Evap. [cm/day] | hCritA [cm] | Transp. [cm/day]
1 | 1 | 0 | 0 | 100000 | 0
2 | 2 | 0 | 0 | 100000 | 0
3 | 3 | 0 | 0 | 100000 | 0
4 | 4 | 0.48 | 0 | 100000 | 0
5 | 5 | 0.02 | 0 | 100000 | 0
6 | 6 | 0 | 0 | 100000 | 0
7 | 7 | 0 | 0 | 100000 | 0
8 | 8 | 0 | 0 | 100000 | 0
9 | 9 | 0 | 0 | 100000 | 0
10 | 10 | 0.16 | 0 | 100000 | 0
11 | 11 | 0 | 0 | 100000 | 0
12 | 12 | 0 | 0 | 100000 | 0
13 | 13 | 0 | 0 | 100000 | 0
14 | 14 | 0 | 0 | 100000 | 0
OK
Cancel
Previous ...
Next ...
Help ...
Add Line
Delete Line
Default Time

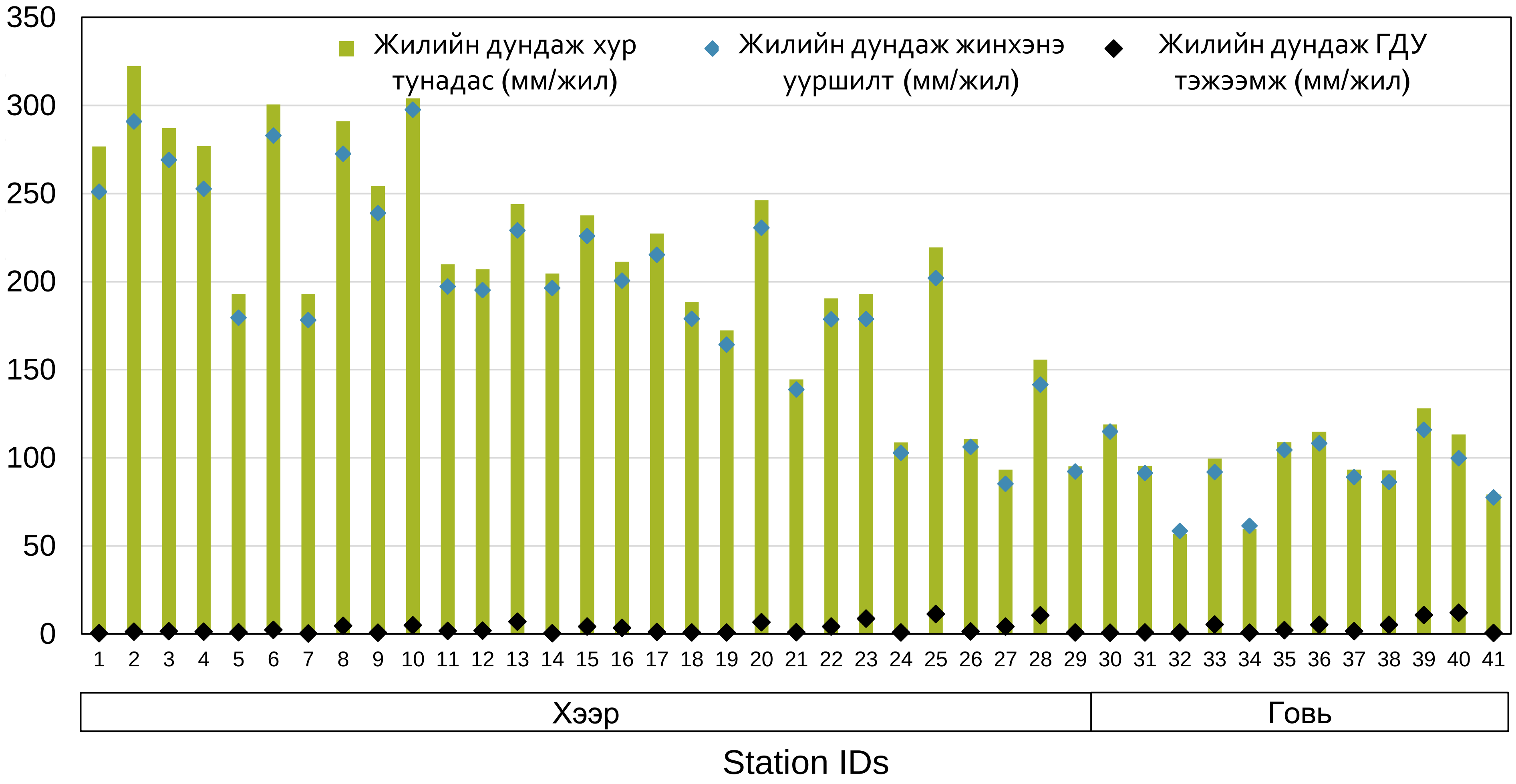

Water Flow Parameters
Mat | Qr [-] | Qs [-] | Alpha [1/cm] | n [-] | Ks [cm/day] | l [-]
1 | 0.0695 | 0.4481 | 0.0088 | 1.5628 | 28.51 | 0.5
2 | 0.0689 | 0.4358 | 0.0091 | 1.537 | 20.72 | 0.5
3 | 0.0698 | 0.4278 | 0.0096 | 1.5211 | 15.53 | 0.5
4 | 0.0687 | 0.4114 | 0.0105 | 1.4919 | 10.41 | 0.5
5 | 0.0674 | 0.4027 | 0.0113 | 1.4702 | 8.92 | 0.5
6 | 0.0673 | 0.3974 | 0.0119 | 1.4512 | 7.72 | 0.5
Soil Catalog
Neural Network Prediction
Temperature Dependence
OK
Cancel
Previous ...
Next ...
Help

АРГАЧЛАЛ	СУДАЛГААНЫ МАТЕРИАЛ ЦУГЛУУЛАХ	ҮР ДҮН

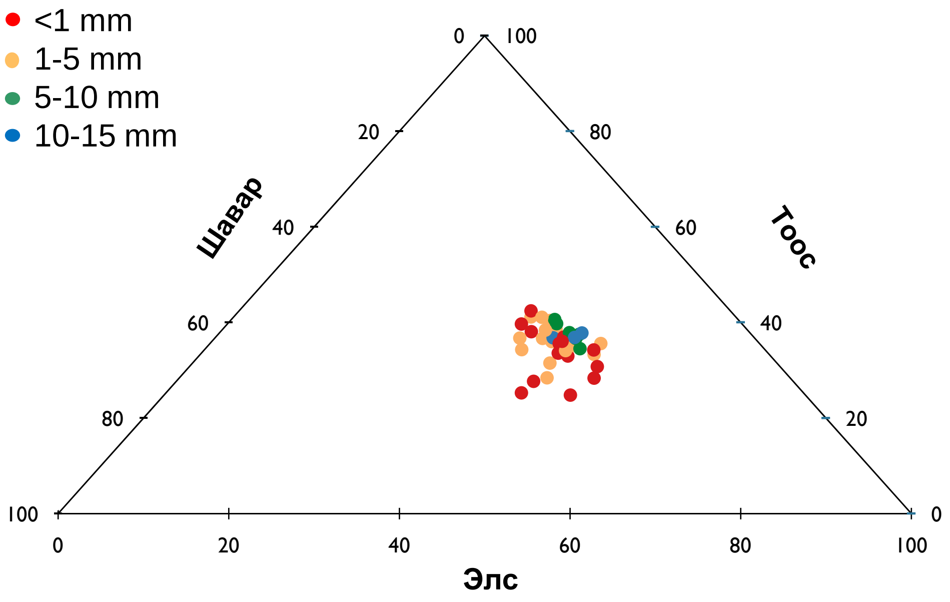


ET_0, $ET_{p,}$ болон E_a, T_a

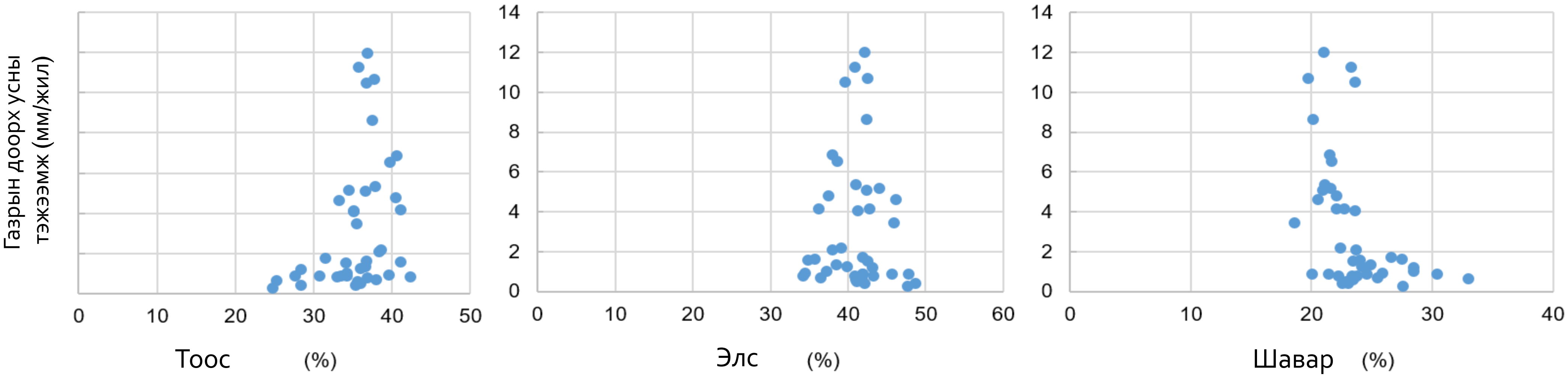
АРГАЧЛАЛ	СУДАЛГААНЫ МАТЕРИАЛ ЦУГЛУУЛАХ	ҮР ДҮН

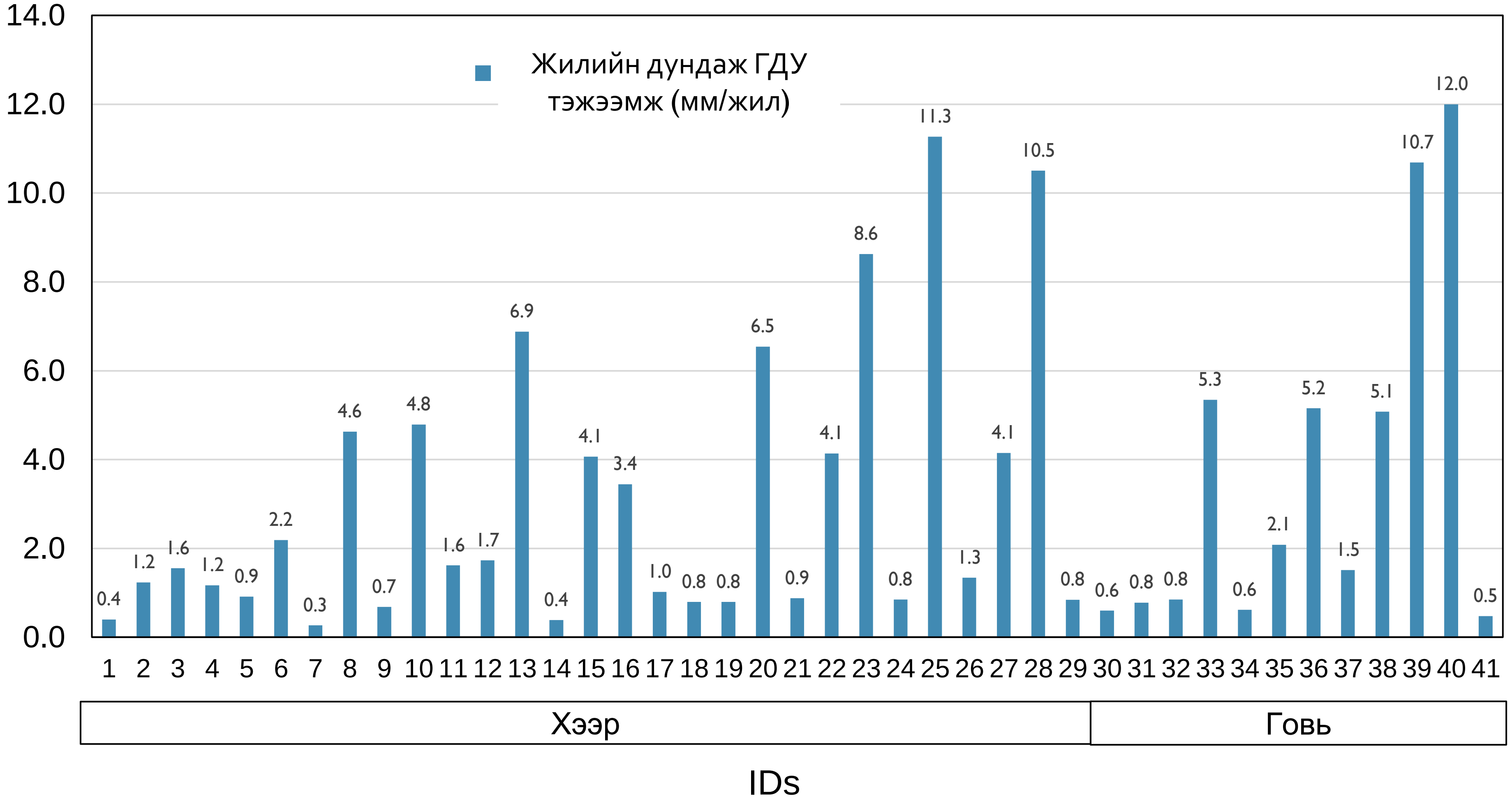


Хур тунадас, ГДУ тэжээмж, жинхэнэ ууршилт

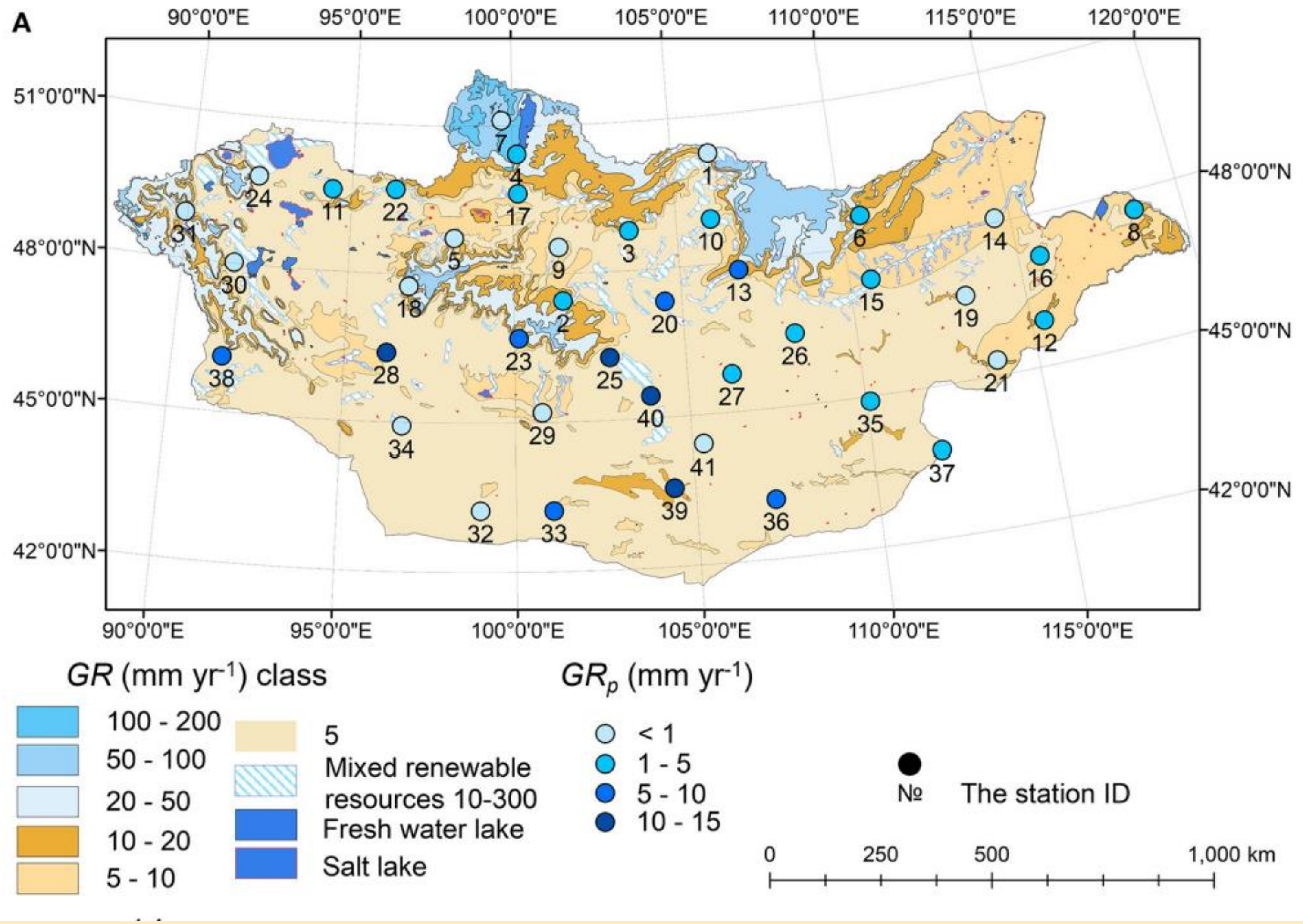


Газрын доорх усны тэжээмж болон ул хөрсний физик шинж чанарын холбоо

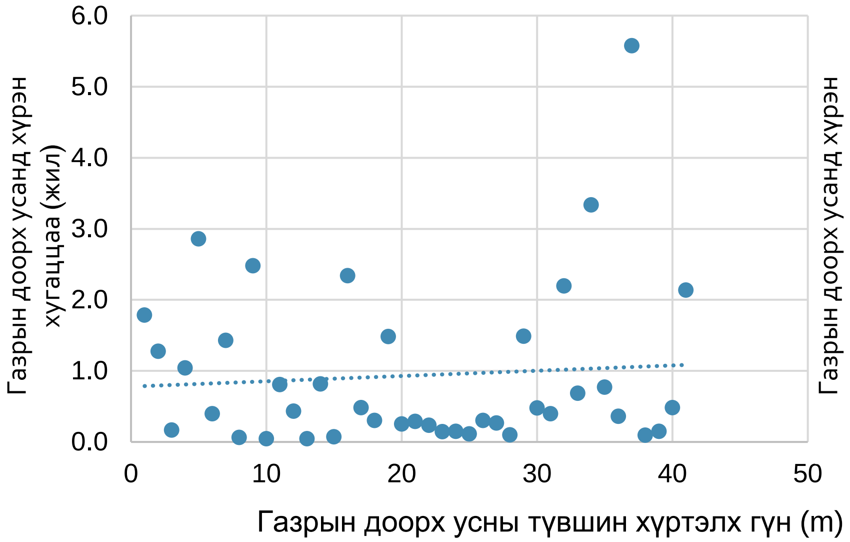


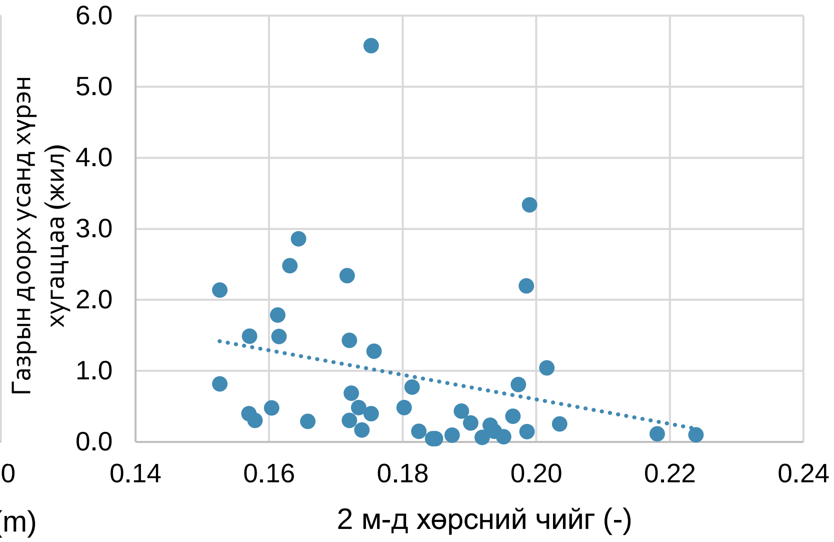


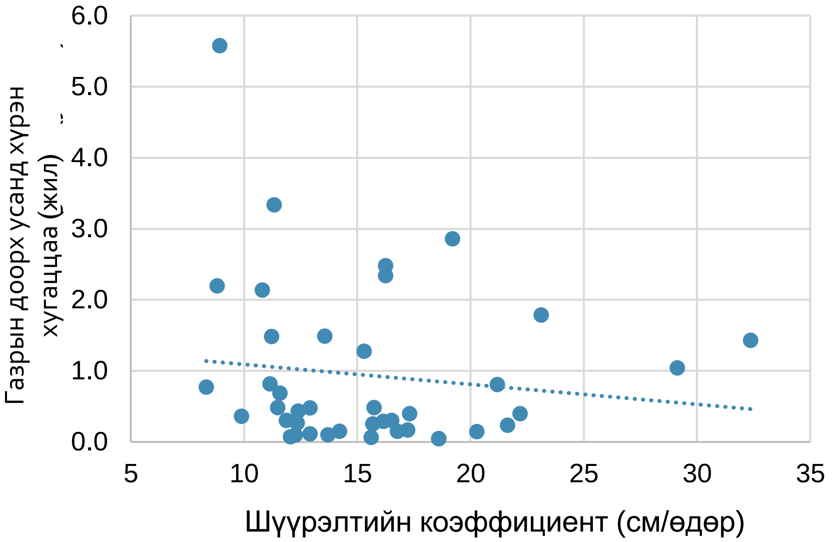
Газрын доорх усны тэжээмж



Our mean annual groundwater recharge results on the Renewable groundwater resource map by Jadambaa et al., (2012). Part 4. Groundwater resources assessment in Integrated Water Management - National Assessment Report Volume I







Газрын доорх усанд хүрэх хугацаа

ҮР ДҮН

- Газрын доорх усны тэжээмж судалгааны цэгүүдэд 1 мм/жил - 12мм/жил буюу хур тунадасны 11% хүртэл ээлж байна.
- Ууршилт хур тунадасны 88% хүртэлх хувийг ээлж байна.

ТОДОРХОЙ БУС БАЙДАЛ

- Ууршилт тооцоход ургамлын коэффициентийг анх удаа Монголд ашигласан.
- Газрын доорх усны тэжээмжийг усаар ханаагүй бүсийн HYDRUS-1D программыг ашиглан тооцолсон.
- Газрын доорх усны тэжээмжийг хээрийн судалгаагүйгээр тооцолсон.

Ургамлын коэффициент

Ууршилт

Газрын доорх усны түвшин

Хөрсний гидравлик параметрүүд

Хөрсний температур

ӨГҮҮЛЭЛ, ХЭВЛЭЛ

- Магистрын дипломын ажил: https://digitalcommons.unl.edu/geoscidiss/131/
- Prediction of Biome-Specific Potential Evapotranspiration in Mongolia under a Scarcity of Weather Data: https://www.mdpi.com/2073-4441/13/18/2470
- Analysis of Groundwater Recharge in Mongolian Drylands Using Composite Vadose Zone Modeling: https://www.frontiersin.org/articles/10.3389/frwa.2022.802208/full
- Batsukh, Khulan. "The analysis of groundwater recharge in Mongolia using vadose zone modeling. Хүрэлтогоот, 2022

ЦААШДЫН СУДАЛГАА

- Land – Atmosphere (Газар – Агаар мандал хосолсон) судалгааны аргыг төрөл бүрийн асуудлыг шийдвэрлэхэд ашиглах (HYDRUS, GeoStudio)
- Цаг уурын цогц станцууд (хөрсний чийг ...)
- Газрын доорх усны тэжээмж тооцох бусад аргуудтай хослуулан судлах
  - Газар доорх усны загварчлал
  - Газрын доорх усны түвшний хэлбэлзэл
  - Эмпирик аргачлалууд
  - Изотоп
  - Лизиметр ...


АНХААРАЛ ТАВЬСАНД
БАЯРЛАЛАА