Remote sensing and Data Fusion for Digital Twin Applications

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www.agromatics.org

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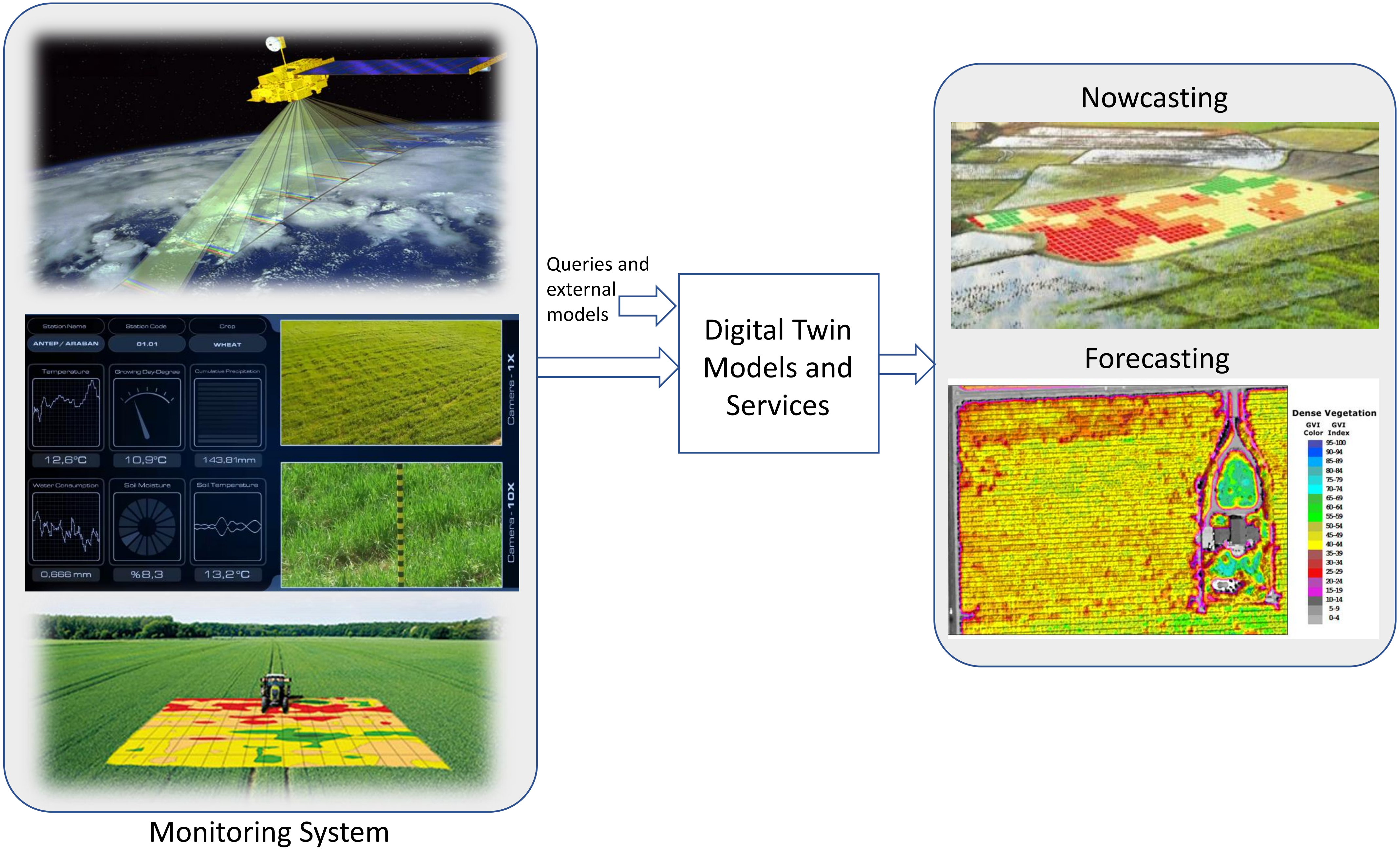
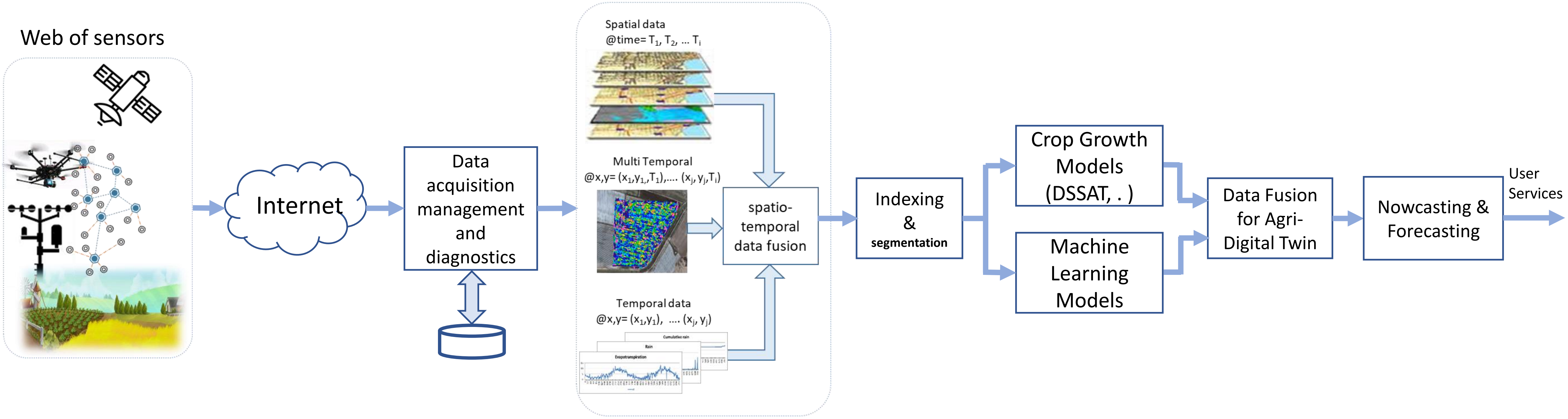
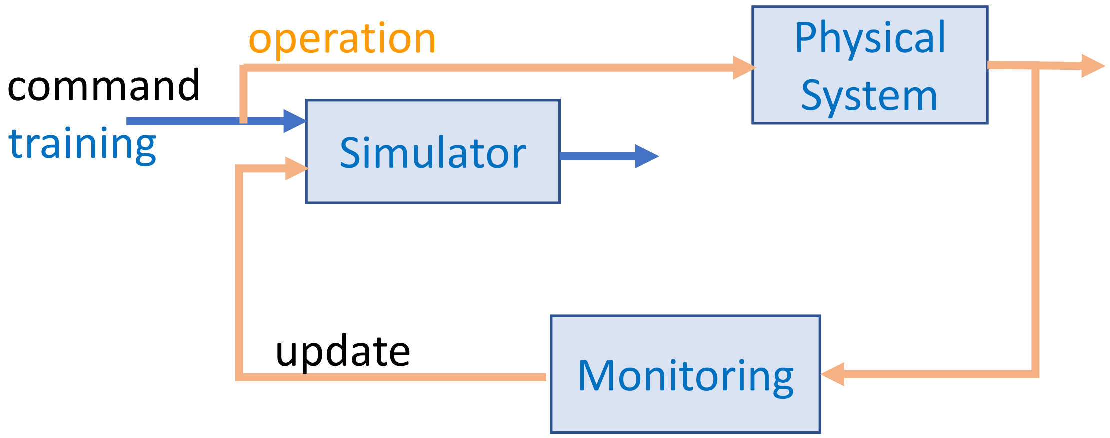
Digital Twinning Concept for Nowcasting and the Forecasting



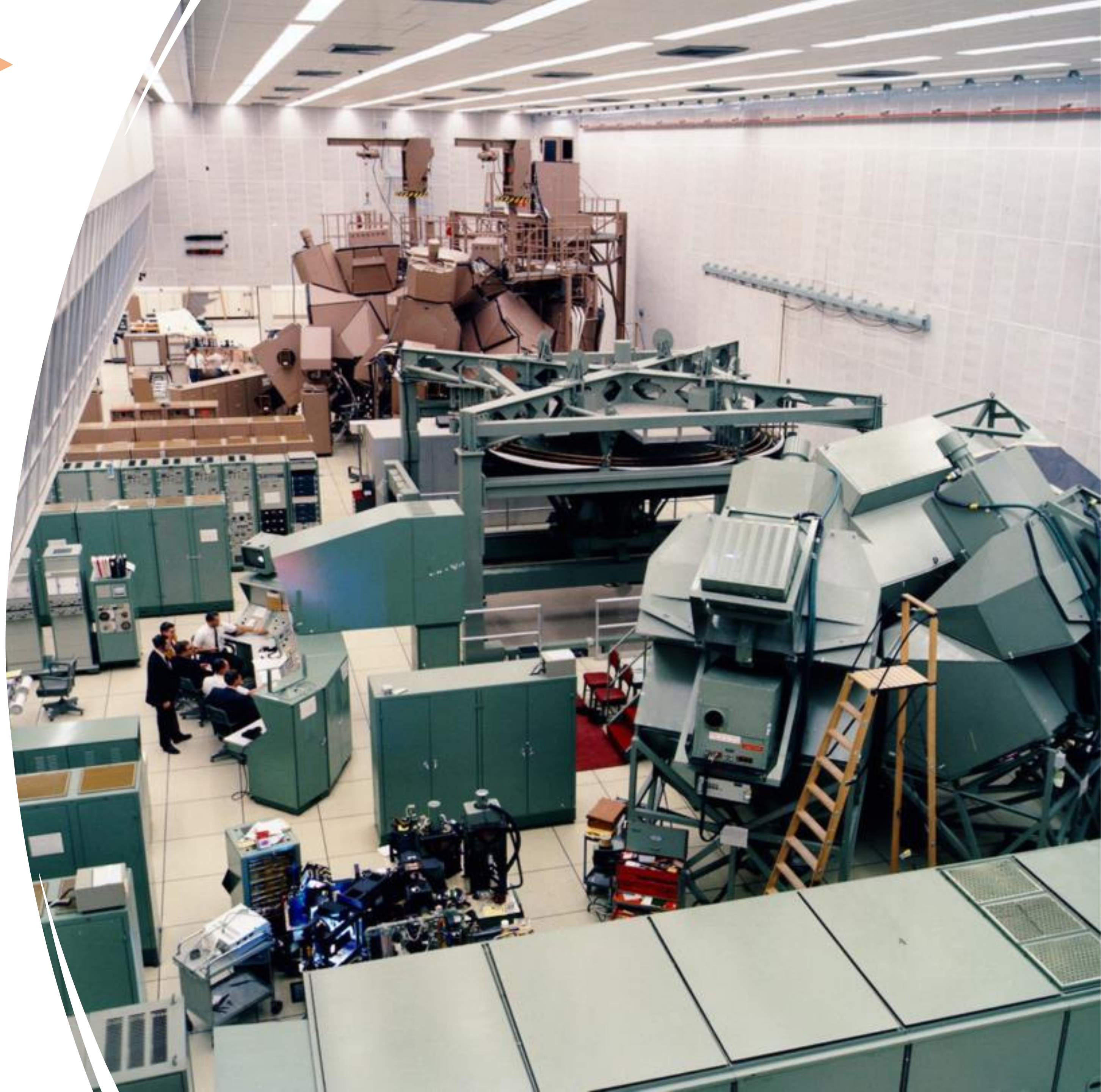
Digital Twinning Process Block Diagram of the AgriTwin





1970

- Simulators that enable system twining helped to prevent disasters in Apollo 13 mission
- Apollo 13 mission was probably the first use of a system's virtual twin. NASA mission controllers were able to rapidly adapt and modify the simulations, to match conditions on the real-life faulty spacecraft, so that they could research, reject, and perfect the strategies required to bring the astronauts home.

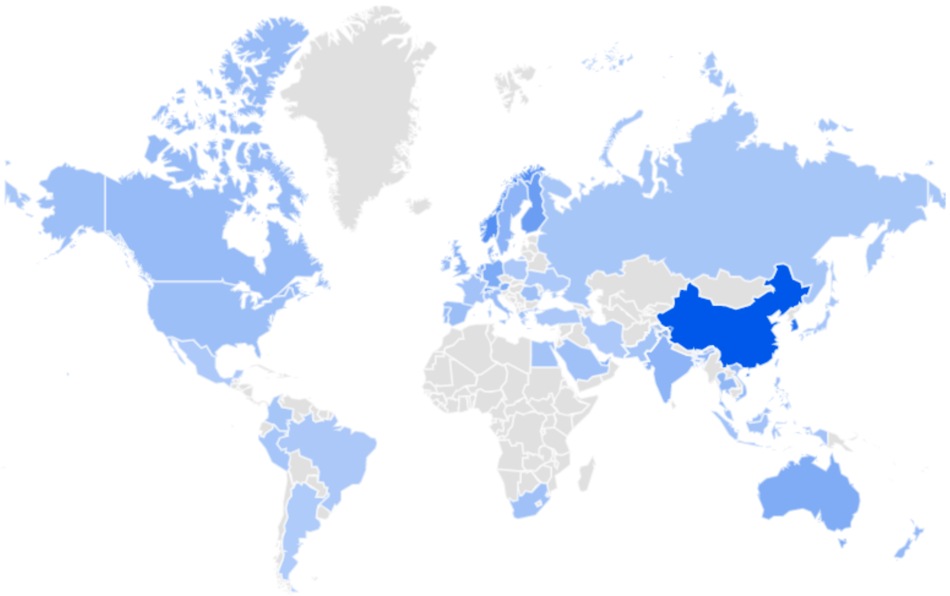


Interest over Time to **Digital Twin**

(Google analytics)

What is Digital Twin ?

Interest by Countries



1	China	100
2	Singapore	89
3	South Korea	80
4	Norway	52
5	Hong Kong	47

Is "Digital Twinning" new or a magic ?

Formal Definition:

"A digital twin is a virtual representation of a physical system, object, or process

that serves as its real-time digital counterpart

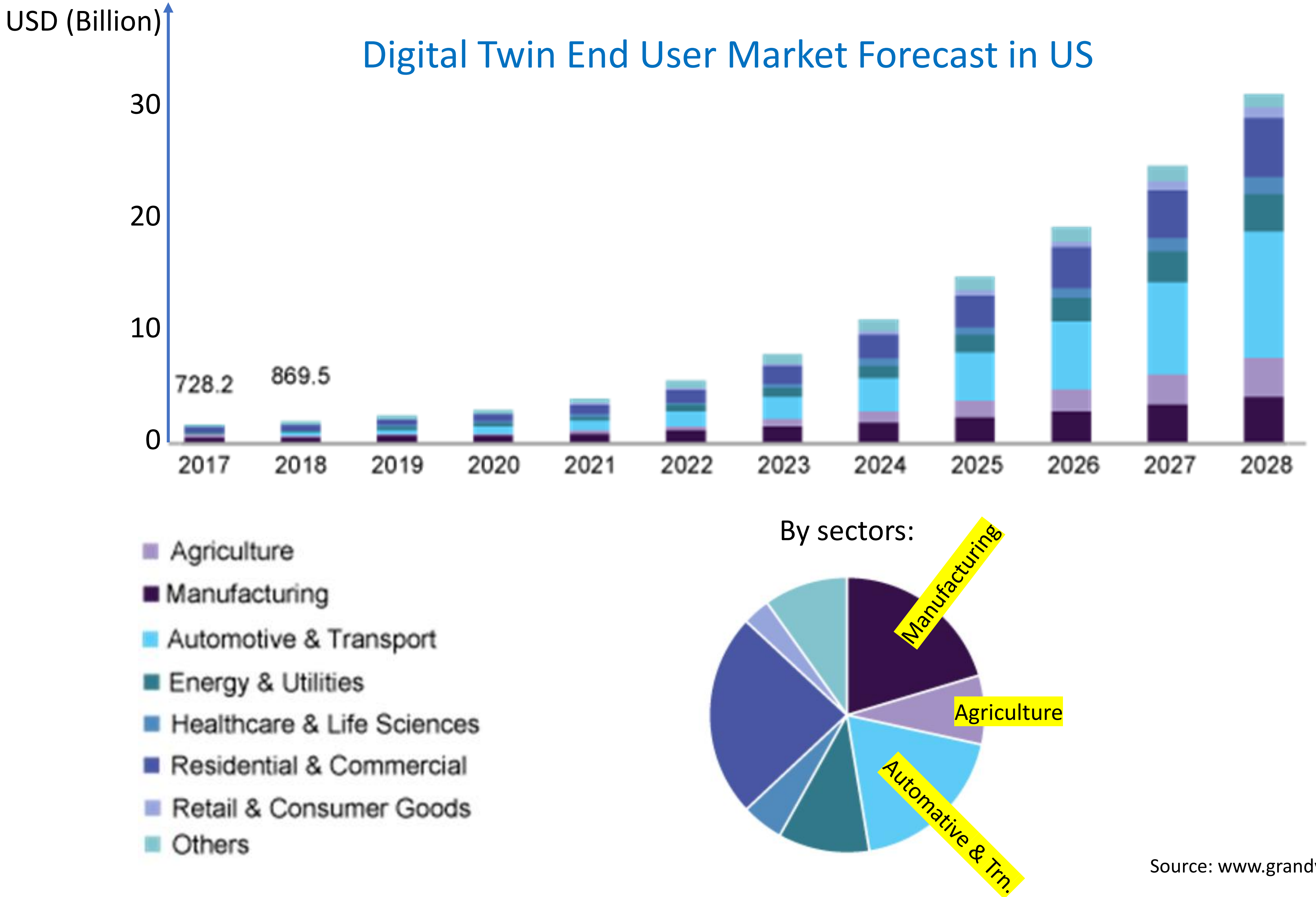
by using ***simulation***, ***machine learning*** *and* ***reasoning***

through ***real-time*** *updating its* ***states***

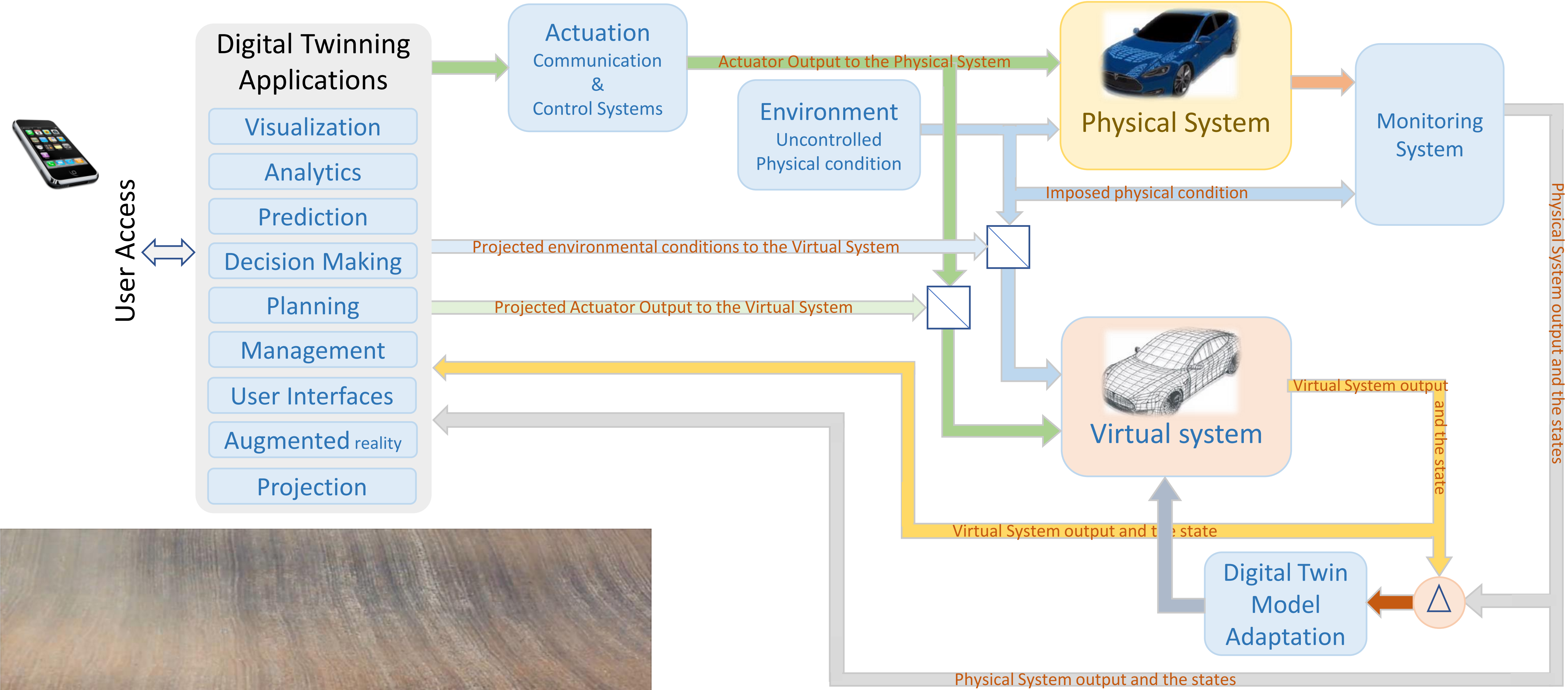
for ***decision-support*** *purposes"*

Definition is new but exists in nature since the evolution of our brains

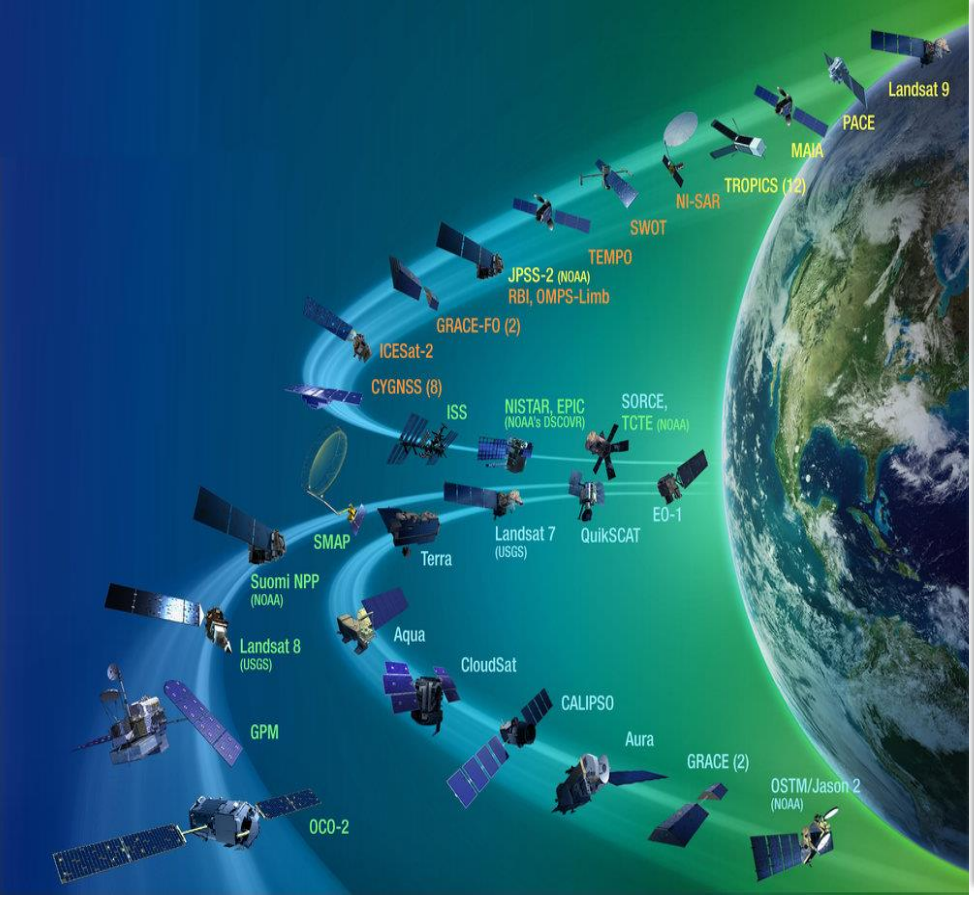
Digital Twin End User Market Forecast in US



Source: www.grandviewresearch.com



Digital Twinning Model

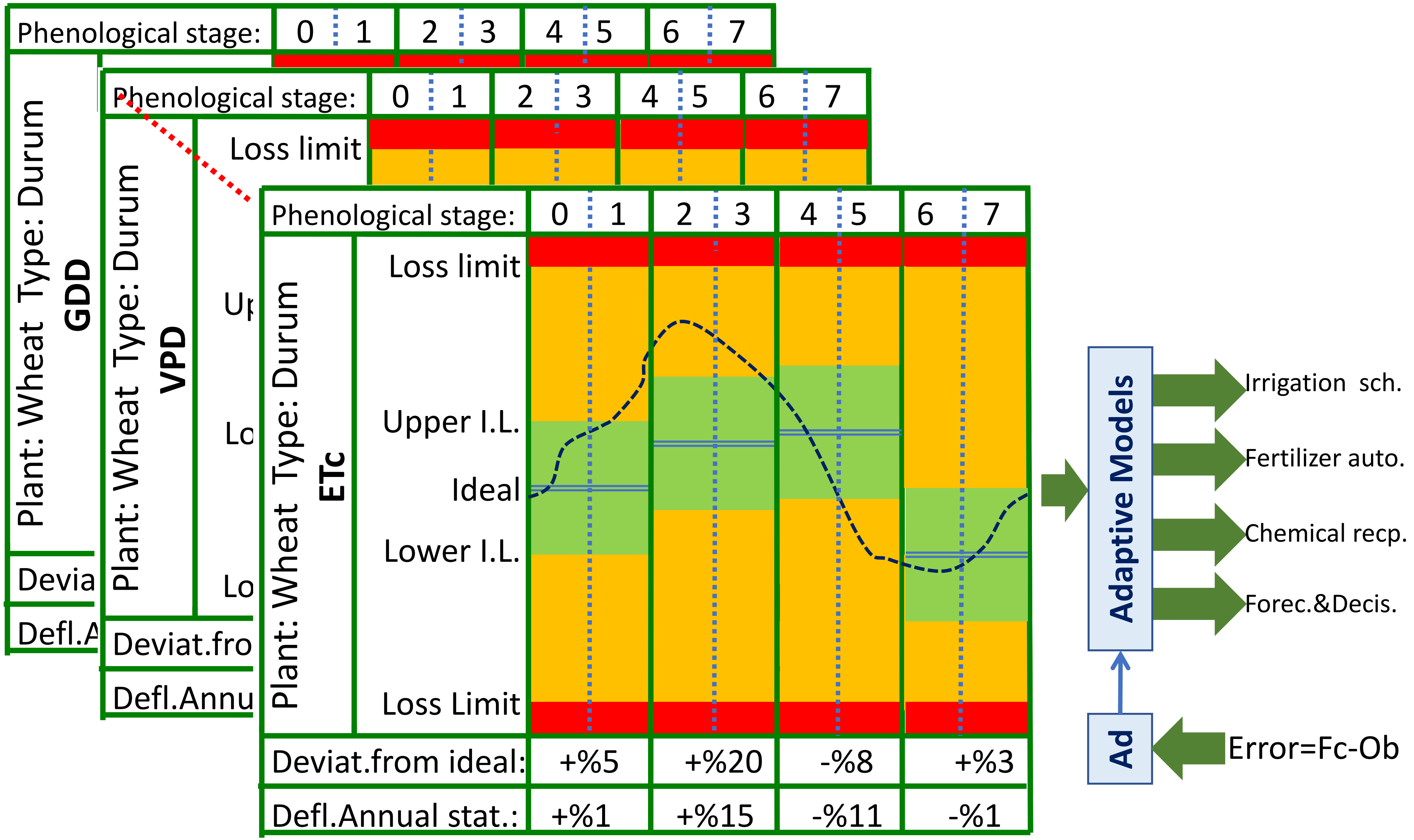


Business process requires spatio-temporal data with known accuracy and tolerance.

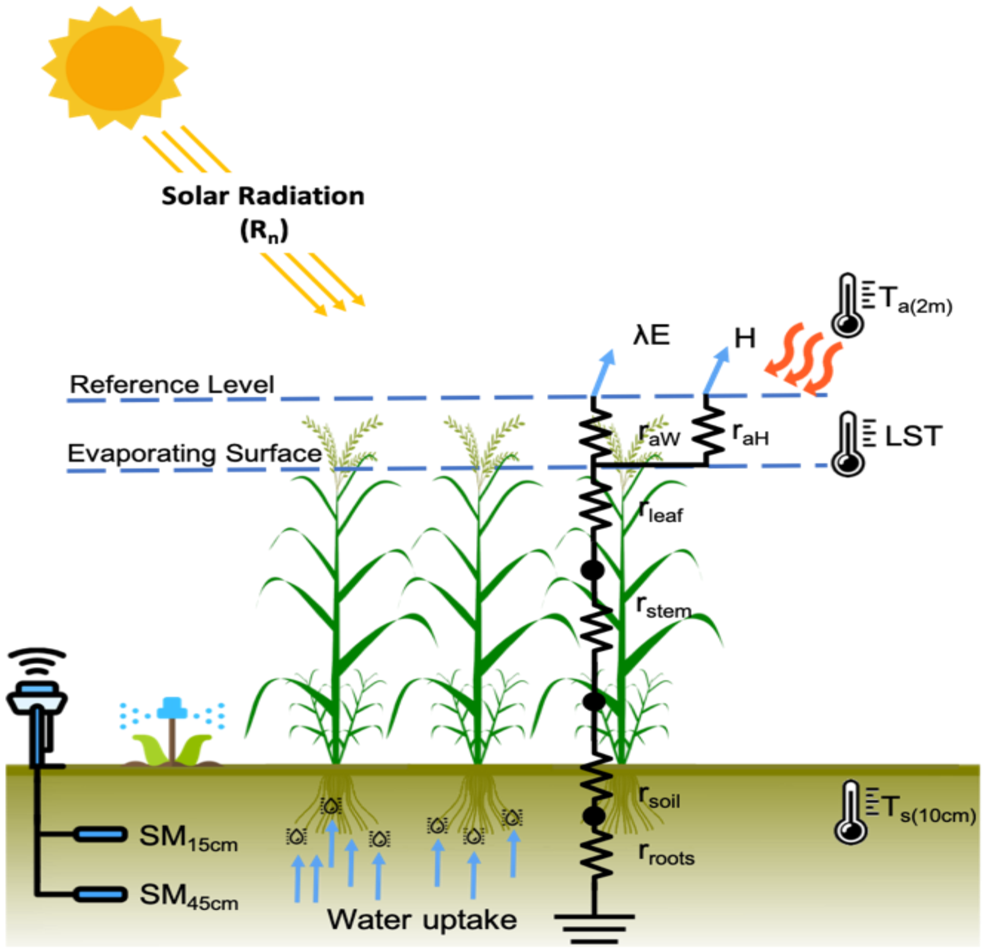
Data driven models require labeled data in relatively short term that satisfies:

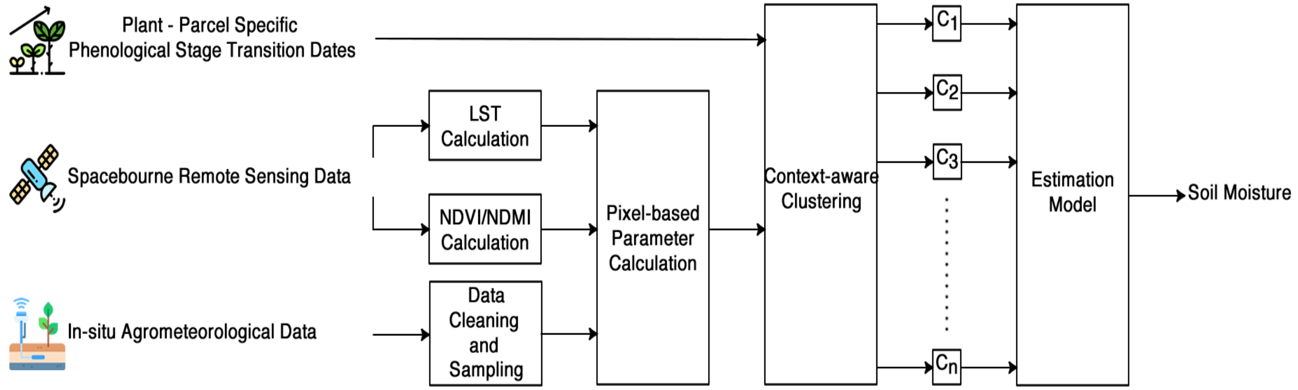
Time varying system   Non-linear   Stochastic   Combinatorial derivatives

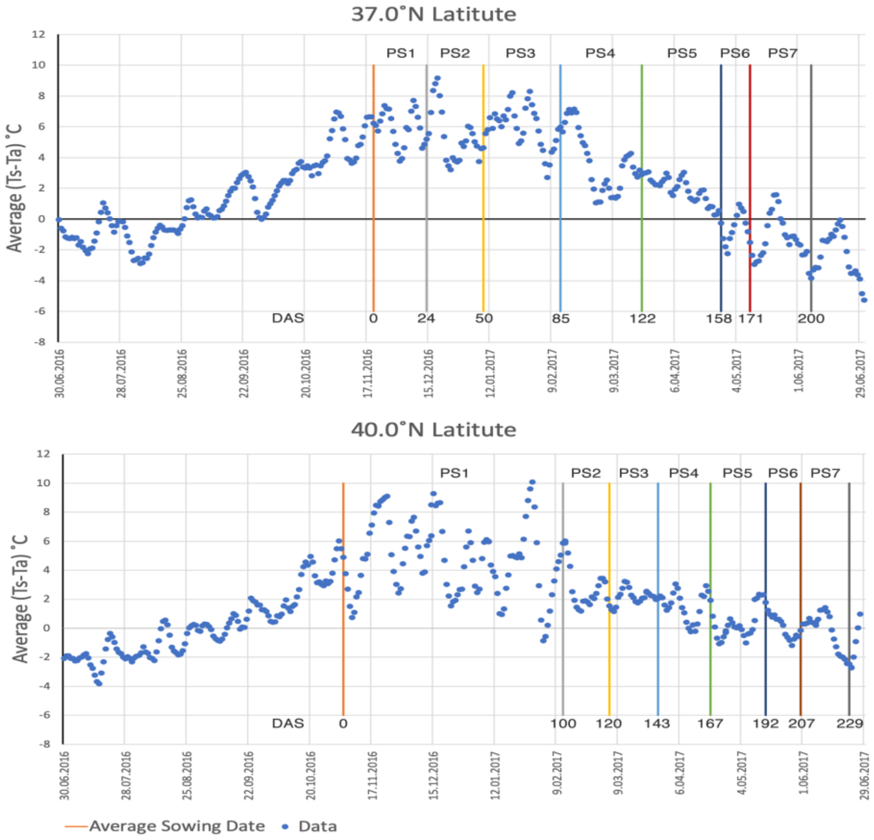
Decision Making / Planning Requirements:



1- Context Matters: Plant as a sensor, context (PS, (Ta-LST))

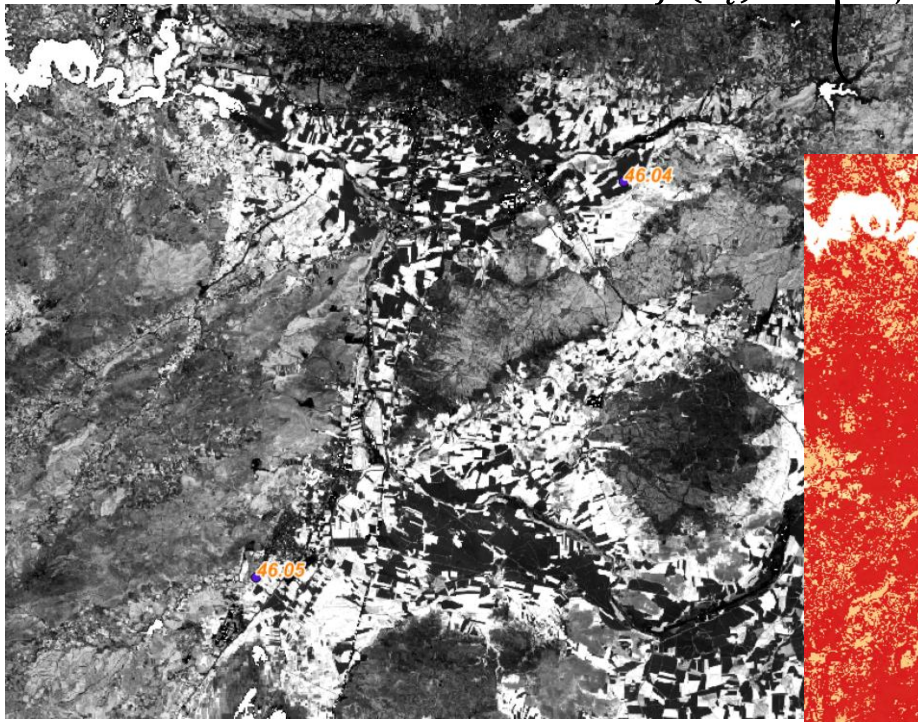






Vegetation Proportion

$$P_v = \left(\frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}\right)^2$$

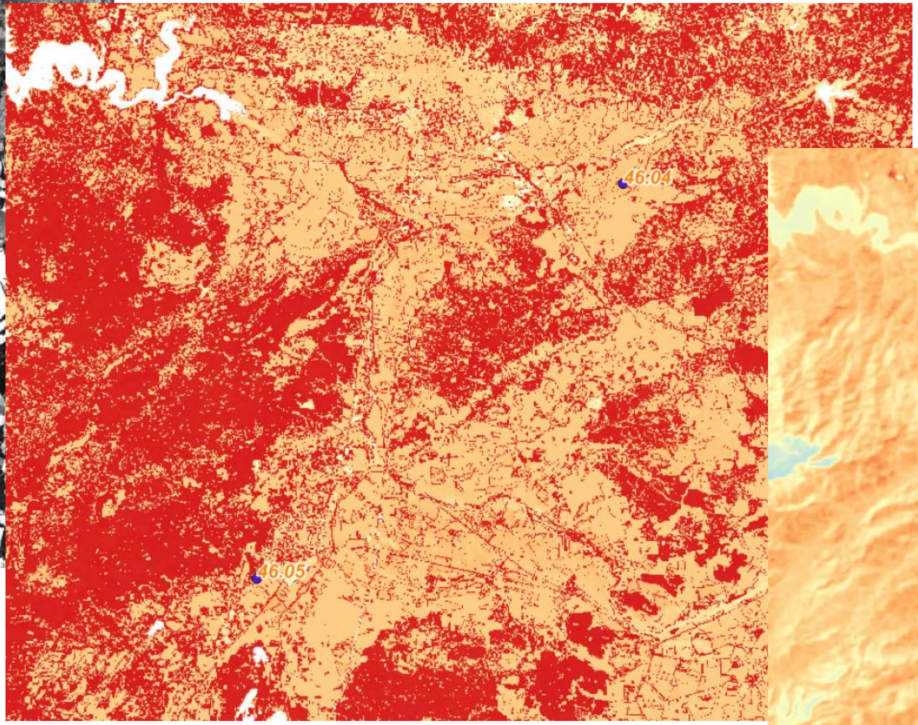


-0.466667
2.03333

Emissivity

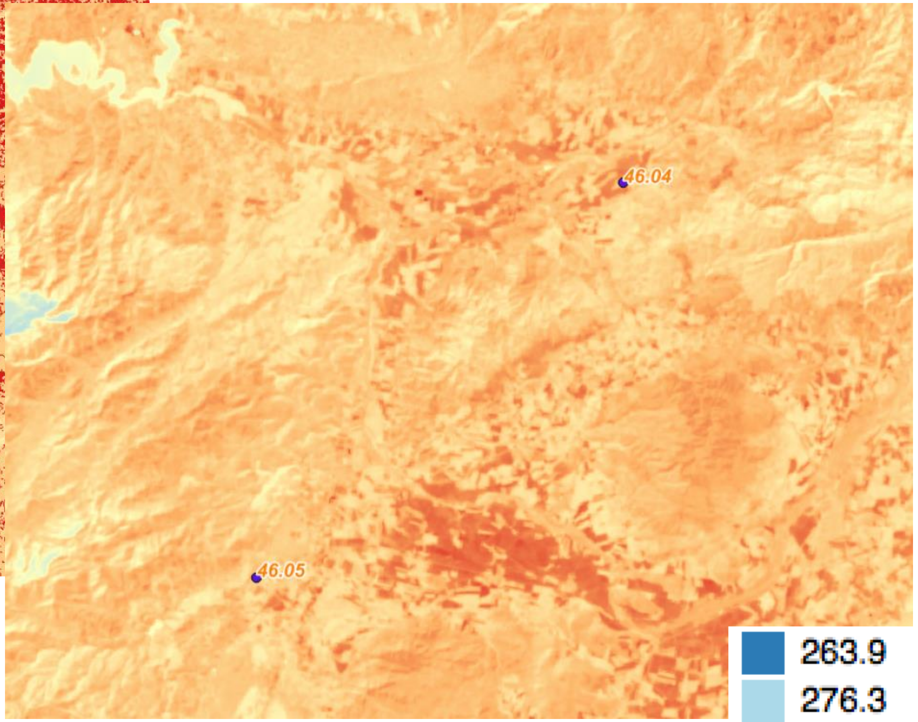
$$f(\varepsilon_i) = \begin{cases} a_i\rho_{red} + b_i, & NDVI < 0.2 \\ \varepsilon_{v,i}P_v + \varepsilon_{s,i}(1 - P_v) + C_i, & 0.2 \leq NDVI \leq 0.5 \\ \varepsilon_{v,i} + C_i, & NDVI > 0.5 \end{cases}$$

$$C_i = (1 - \varepsilon_{s,i})\varepsilon_{v,i} * F' * (1 - P_v)$$



0.9298
0.9439
0.9581
0.9722
0.9863

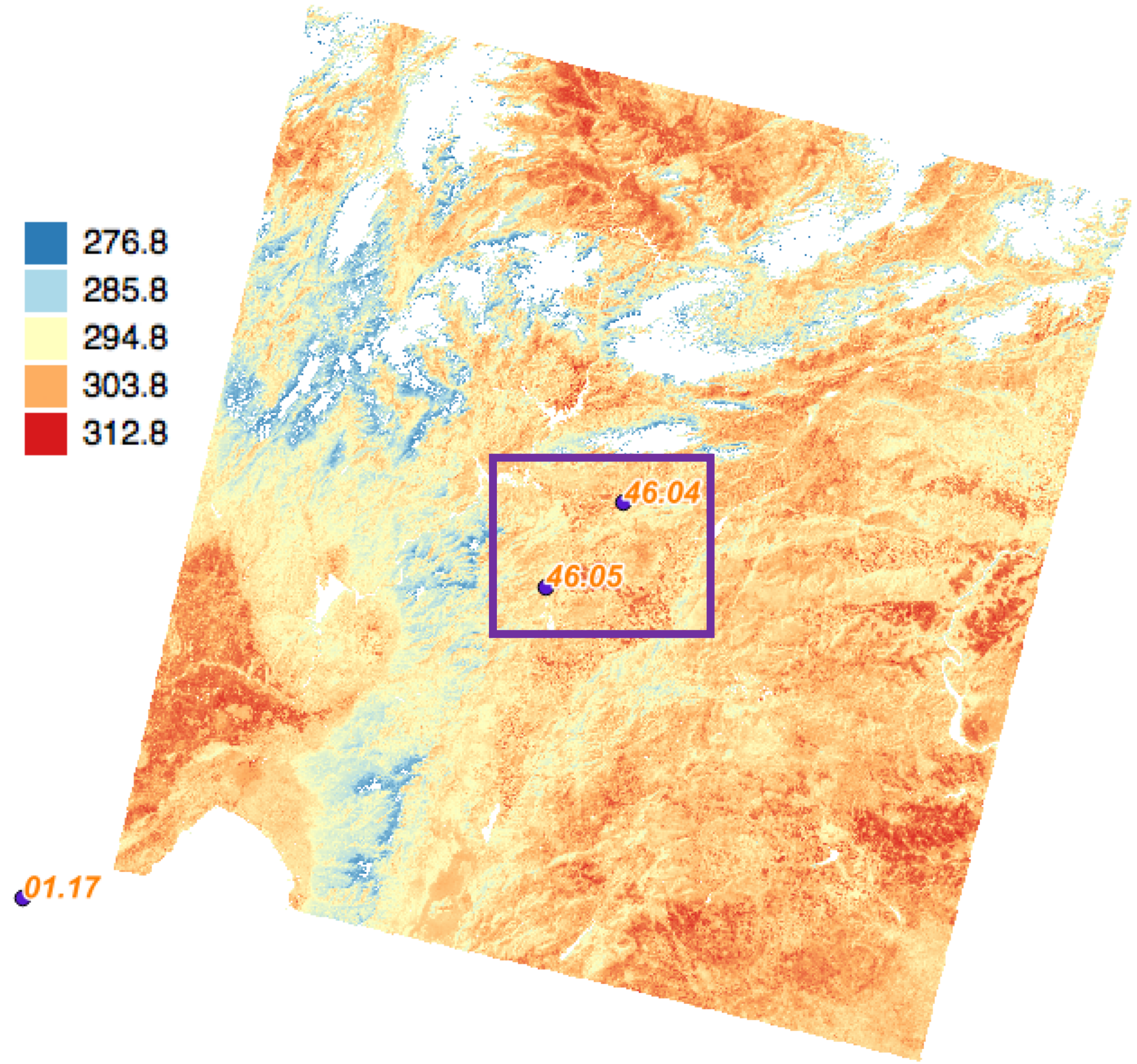
Brightness Temperature (K)

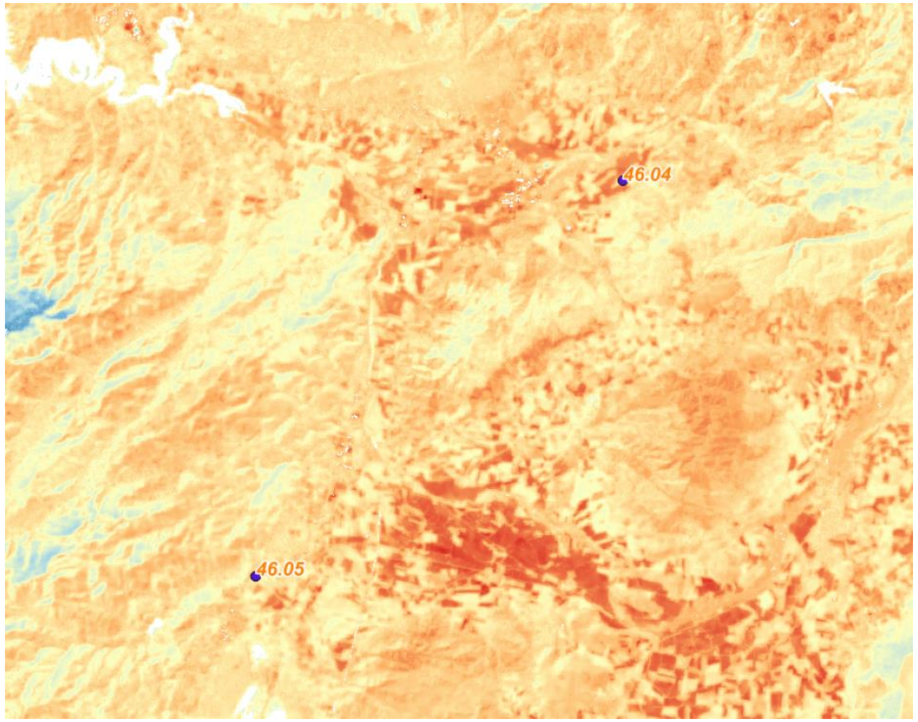


263.9
276.3
288.6
301
313.4

Land Surface Temperature

$$\frac{T_B}{1 + \left(\lambda * {T_B}/{p}\right) * \ln(\varepsilon)}$$

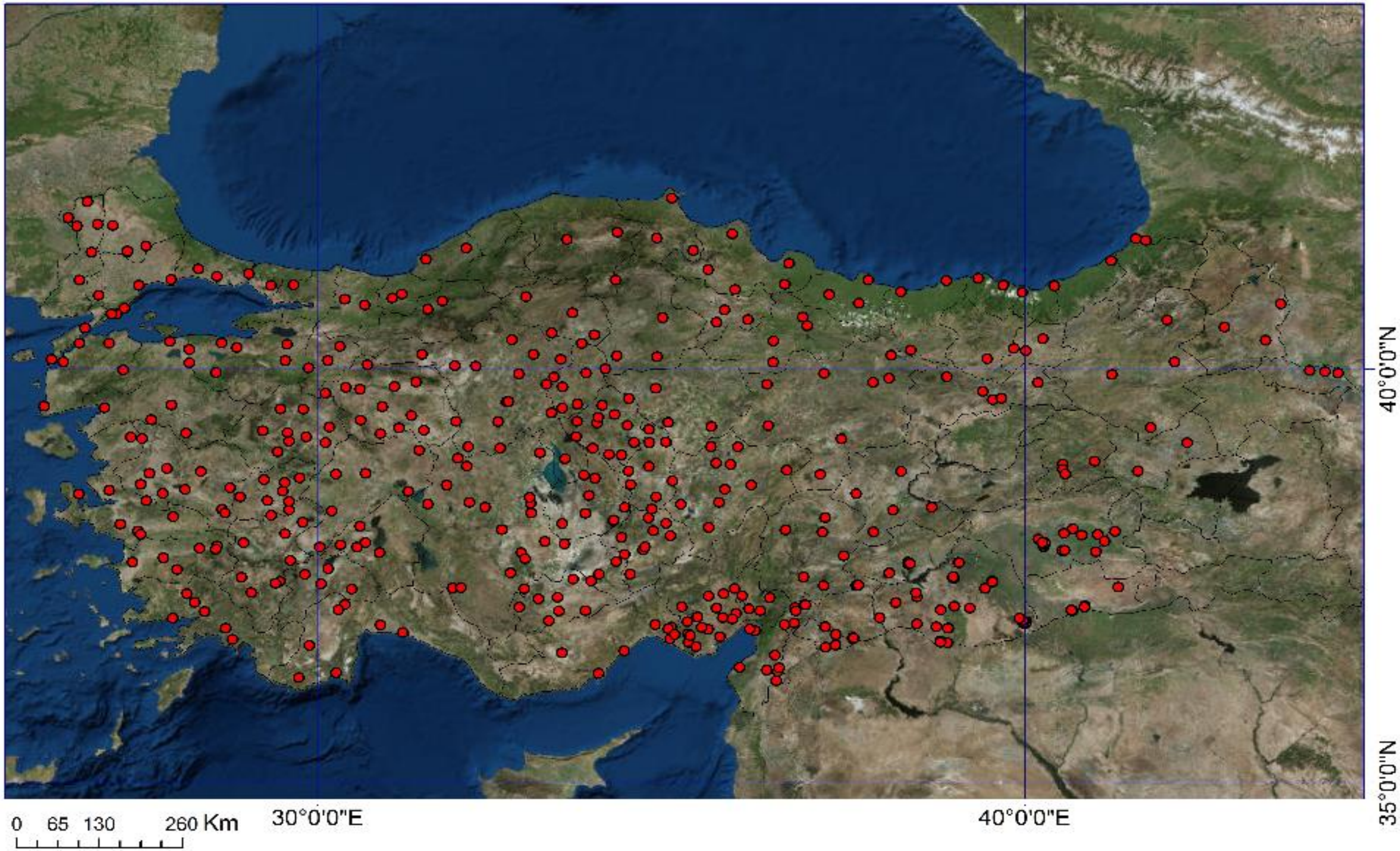


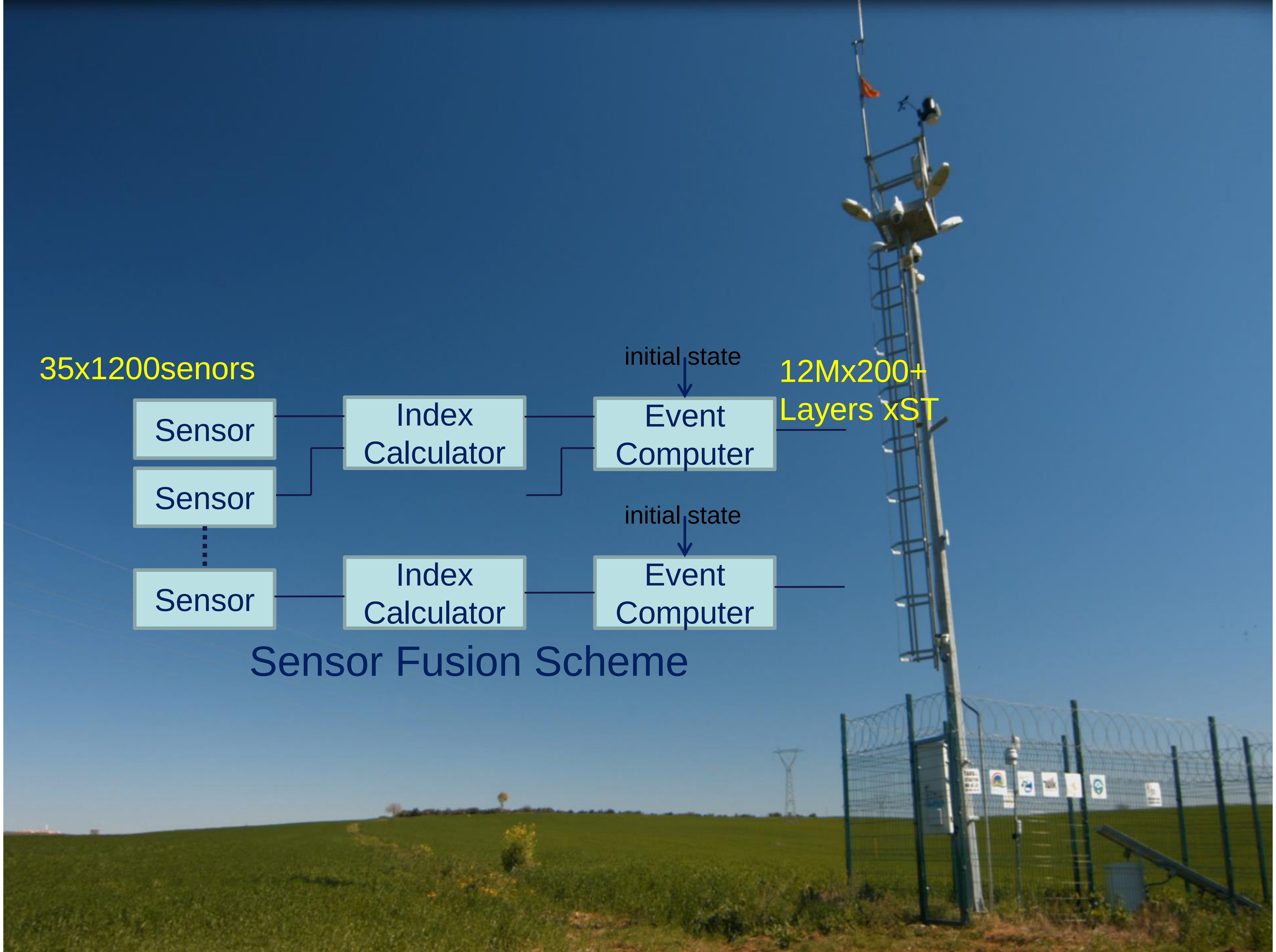


=VLOOKUP(D2;'/Users/aydaaktas/Documents/Doktora/Agro-Geo2018/Data/46_04/[46_04_10mins.xlsx]Sampling'!$L$3:$Q$224;6;0)

Landsat Product Identifier	Landsat Scene Identifier	Acquisition Date	PS	Pixel Quality	LST (K)	LST ©	Ts-Ta (SSDM)
LC08_L1TP_174034_2016111	LC81740342016322LGN01	17.11.2016	1	Clear	289,13	17,98	3,36
LE07_L1TP_174034_2016112	LE71740342016330NPA00	25.11.2016	1	Clear	290,91	19,76	6,78
LC08_L1TP_174034_2016120	LC81740342016338LGN01	3.12.2016	1	Clear	285,95	14,80	2,57
LE07_L1TP_174034_2016121	LE71740342016346NPA00	11.12.2016	2	Clear	286,95	15,80	3,80
LC08_L1TP_174034_2016121	LC81740342016354LGN02	19.12.2016	2	Clear	280,79	9,64	3,62
LE07_L1GT_174034_2016122	LE71740342016362NPA00	27.12.2016	2				
LC08_L1TP_174034_2017010	LC81740342017004LGN01	4.01.2017	2	Cloud	279,23		
LE07_L1TP_174034_2017011	LE71740342017012NPA00	12.01.2017	2	Clear	279,93	8,78	2,53
LC08_L1TP_174034_2017012	LC81740342017020LGN01	20.01.2017	3	Clear	285,79	14,64	4,02
LE07_L1TP_174034_2017012	LE71740342017028NPA00	28.01.2017	3	Snow			
LC08_L1TP_174034_2017020	LC81740342017036LGN00	5.02.2017	3	Cloud	272,21		
LE07_L1TP_174034_2017021	LE71740342017044NPA00	13.02.2017	3	Clear	287,91	16,76	6,41
LC08_L1TP_174034_2017022	LC81740342017052LGN00	21.02.2017	3	Clear	293,59	22,44	8,26
LE07_L1TP_174034_2017030	LE71740342017060NPA00	1.03.2017	4				
LC08_L1TP_174034_2017030	LC81740342017068LGN00	9.03.2017	4	Cloud	288,23	17,08	5,27
LE07_L1GT_174034_2017031	LE71740342017076SG100	17.03.2017	4				
LC08_L1TP_174034_2017032	LC81740342017084LGN00	25.03.2017	4	Clear	299,45	28,30	9,07
LE07_L1GT_174034_2017040	LE71740342017092SG100	2.04.2017	5	Cloud	241,40		
LC08_L1TP_174034_2017041	LC81740342017100LGN00	10.04.2017	5	Clear	294,20	23,05	7,74
LE07_L1TP_174034_2017041	LE71740342017108SG100	18.04.2017	5	Cloud	249,41		
LC08_L1TP_174034_2017042	LC81740342017116LGN00	26.04.2017	5	Clear	306,18	35,03	10,43
LE07_L1TP_174034_2017050	LE71740342017124SG100	4.05.2017	6	Clear	297,19	26,04	
LC08_L1TP_174034_2017051	LC81740342017132LGN00	12.05.2017	7	Clear	308,82	37,67	9,75
LE07_L1GT_174034_2017052	LE71740342017140SG100	20.05.2017	7				
LC08_L1TP_174034_2017052	LC81740342017148LGN00	28.05.2017	7	Clear	306,28	35,13	
LE07_L1TP_174034_2017060	LE71740342017156SG100	5.06.2017	7	Clear	310,55	39,40	8,17
LC08_L1TP_174034_2017061	LC81740342017164LGN00	13.06.2017		Clear	311,70	40,55	9,75
LE07_L1TP_174034_2017062	LE71740342017172SG100	21.06.2017		Cloud	265,38		

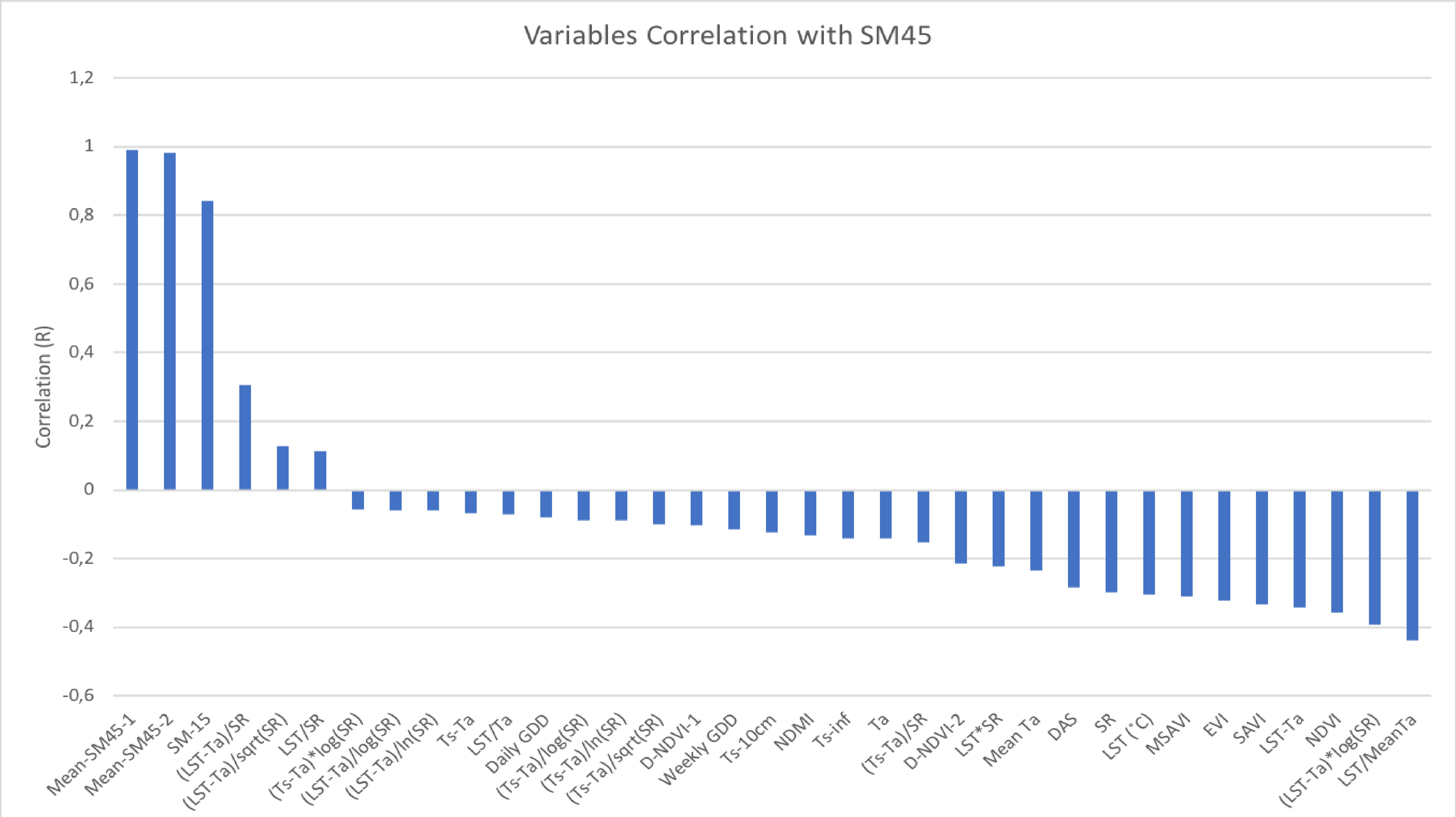
Distribution of monitoring stations in Turkey
(first 440 of 1200)





Sensor Fusion Scheme

Nowcast or forecast of Invisible : Root zone soil moisture example

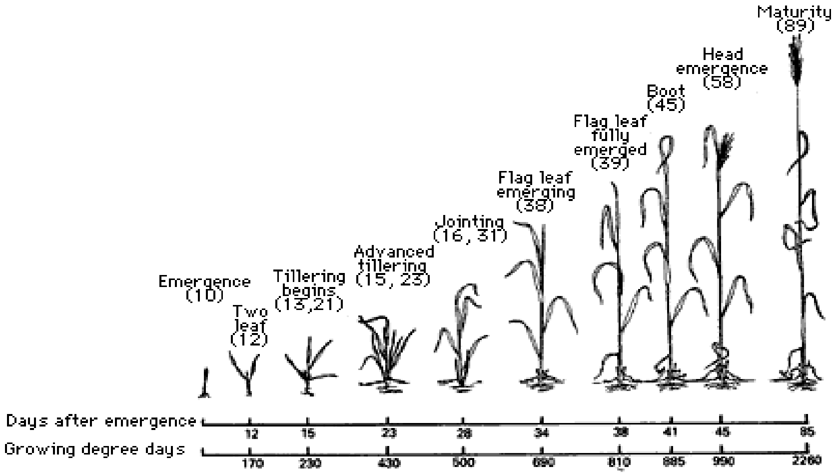


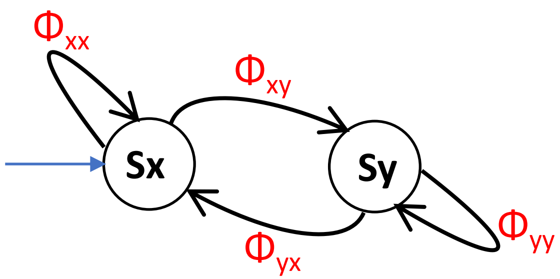
	SM-45	SM-15	DAS	Daily GDD	Weekly GDD	Mean Ta	LST/MeanTa	D-NDVI-1	Mean-SM45-1	D-NDVI-2	Mean-SM45-2	NDVI
SM-45	1											
SM-15	0.66516852	1										
DAS	0.72348061	0.35826524	1									
Daily GDD	-0.3080048	0.03665946	-0.6242423	1								
Weekly GDD	-0.4201387	-0.0728364	-0.5610309	0.73704909	1							
Mean Ta	-0.6262016	-0.2468563	-0.7103212	0.80262676	0.90209283	1						
LST/MeanTa	-0.3475101	0.21872037	-0.2613882	0.32311785	0.3111267	0.41576053	1					
D-NDVI-1	-0.376261	0.12620578	-0.3973817	0.09779169	0.01562527	0.0860722	0.01455259	1				
Mean-SM45-	0.98722114	0.62168421	0.73980289	-0.3411336	-0.4412476	-0.6486856	-0.3759203	-0.3385097	1			
D-NDVI-2	-0.0858949	0.41278744	-0.3108008	0.10432127	0.01786673	-0.0212358	-0.0765479	0.89615879	-0.0983653	1		
Mean-SM45-	0.9824091	0.61151336	0.73842043	-0.3373671	-0.438957	-0.6508344	-0.3823654	-0.3321934	0.99937828	-0.0991339	1	
NDVI	-0.4128661	-0.0138345	-0.5454967	-0.0546087	-0.0115806	-0.0055315	0.07564698	0.79387237	-0.4009328	0.77294764	-0.3959694	1
EVI	-0.4310242	-0.091013	-0.5915214	-0.0086263	0.03791218	0.03986958	-0.1340884	0.79996715	-0.4313044	0.81150096	-0.4280079	0.94718831
SAVI	-0.3183441	0.01226298	-0.5120801	-0.0928504	-0.0768815	-0.085171	-0.0923523	0.79812497	-0.3094518	0.81966941	-0.3055452	0.97587376
MSAVI	-0.1771784	0.09796461	-0.4579616	-0.1052205	-0.0779619	-0.1360798	-0.1537081	0.66923693	-0.1995751	0.79850551	-0.2001052	0.925716
NDMI	0.80287442	0.58081254	0.56753999	-0.1851849	-0.2728218	-0.4253238	0.07881733	-0.4017349	0.83791866	-0.2740833	0.8406764	-0.3674043
Ts-inf	-0.4843896	-0.1095561	-0.8032544	0.90605889	0.85054508	0.90643664	0.337141	0.07856674	-0.538771	0.10757129	-0.541518	0.08807302
Ta	-0.3411092	-0.0104438	-0.5594171	0.87044491	0.630748	0.83406945	0.34992618	0.13846689	-0.3604686	0.05109729	-0.3651478	-0.1365134
SR	-0.4950262	-0.2080795	-0.7168362	0.92167999	0.65578295	0.79216793	0.13753019	0.19870627	-0.5402875	0.17331212	-0.5387709	0.04781506
Ts-10cm	-0.47894	0.05387788	-0.6077567	0.87357192	0.80649359	0.91395801	0.46638781	0.23924011	-0.5146201	0.18417524	-0.5191663	-0.019642
Ts-Ta	-0.4206372	-0.1639327	-0.7039684	0.5471344	0.70581504	0.58525176	0.17673394	-0.0175181	-0.4873906	0.11884063	-0.4869454	0.28123554
(Ts-Ta)/SR	-0.3939484	-0.025606	-0.7864339	0.44381666	0.56944255	0.45485032	0.06270615	0.41334342	-0.4306747	0.54068995	-0.4278287	0.67524634
(Ts-Ta)/log(S	-0.4263473	-0.1369474	-0.7446388	0.53007043	0.68929172	0.56541214	0.14897539	0.09400683	-0.4863566	0.23079864	-0.4851377	0.39537411
(Ts-Ta)/ln(SR	-0.4263129	-0.1369158	-0.7446853	0.53020077	0.68931666	0.56545664	0.14887583	0.09408548	-0.4863266	0.23089837	-0.4851072	0.39538093
LST (˚C)	-0.6387603	-0.1946217	-0.7030259	0.64567447	0.54096192	0.76979357	0.30414442	0.29318825	-0.68631	0.20226595	-0.6972562	0.08467609
LST-Ta	-0.6184731	-0.2731297	-0.5139498	0.14776482	0.21356175	0.36126948	0.12417465	0.30025446	-0.6701062	0.24781797	-0.681783	0.24733227
(LST-Ta)/SR	0.39574681	0.46775289	0.46586306	-0.7533263	-0.6342829	-0.7118513	0.07442397	0.09145014	0.39216744	0.20250498	0.38133619	0.20391441
(LST-Ta)/log(	-0.3291487	-0.0122527	-0.1841691	-0.2615031	-0.1342047	-0.0441552	0.12133943	0.2990285	-0.3724367	0.30112009	-0.3879128	0.28815327
(LST-Ta)/ln(S	-0.329206	-0.0121737	-0.1842051	-0.2615138	-0.1341582	-0.0440876	0.12142041	0.29923037	-0.3724802	0.30128214	-0.3879577	0.28828974
(Ts-Ta)*log(S	-0.4097925	-0.1697225	-0.6731505	0.5614745	0.70957228	0.59465489	0.19604735	-0.0839915	-0.4811889	0.05288398	-0.4814438	0.20351356
(LST-Ta)*log(	-0.718513	-0.3850967	-0.6775105	0.39704667	0.40146217	0.56307346	0.13464848	0.26505302	-0.771461	0.19529665	-0.7791249	0.21773649
LST*SR	-0.5200991	-0.1679743	-0.761311	0.90941857	0.60438181	0.77561727	0.28788445	0.16811866	-0.5725454	0.13977788	-0.5737559	0.0555697
LST/SR	-0.199424	0.19079318	-0.1168021	-0.0798746	-0.0131331	0.16814329	0.22006964	0.31946674	-0.2352182	0.28987476	-0.2582535	0.06465212
LST/Ta	-0.1455785	0.08431196	0.02213514	0.00795127	-0.1255594	0.17757628	0.29997042	0.30491624	-0.1184985	0.09379128	-0.1309395	-0.0482644
(Ts-Ta)/sqrt(	-0.427485	-0.1263103	-0.7617501	0.51313193	0.67388074	0.54862161	0.12985207	0.15440481	-0.4823959	0.2887	-0.4805827	0.45811693
(LST-Ta)/sqrt	-0.0996721	0.15156638	0.06723763	-0.4892986	-0.3364211	-0.2915325	0.08965332	0.25716506	-0.1314341	0.28926919	-0.1475599	0.25275674

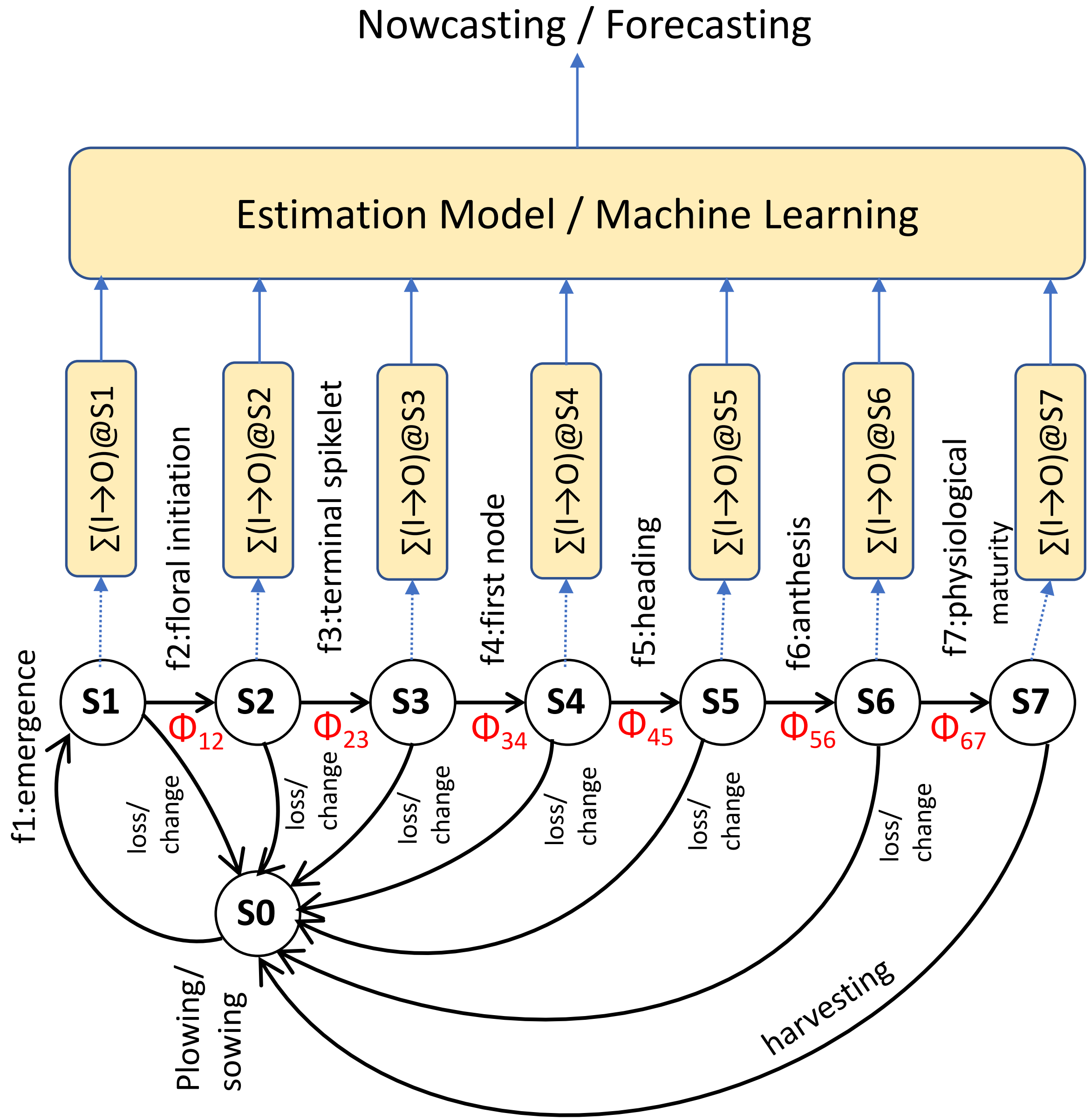
	EVI	SAVI	MSAVI	NDMI	Ts-inf	Ta	SR	Ts-10cm	Ts-Ta	(Ts-Ta)/SR	(Ts-Ta)/log(SR	(Ts-Ta)/ln(SR)
EVI	1											
SAVI	0.97897738	1										
MSAVI	0.94461772	0.96569618	1									
NDMI	-0.5446823	-0.380447	-0.3237039	1								
Ts-inf	0.16585322	0.05237927	0.06533543	-0.3878513	1							
Ta	-0.1065729	-0.1832391	-0.2395443	-0.1747102	0.79245294	1						
SR	0.17025566	0.03750583	0.02215241	-0.5111266	0.89133482	0.82126993	1					
Ts-10cm	0.03603079	-0.0734399	-0.1298047	-0.3608552	0.87299353	0.89797448	0.83129718	1				
Ts-Ta	0.37438937	0.27250602	0.3512356	-0.438304	0.77737283	0.23235901	0.57437011	0.46601472	1			
(Ts-Ta)/SR	0.74221301	0.68405986	0.72612676	-0.416746	0.65968278	0.18769357	0.48509838	0.38376772	0.85839016	1		
(Ts-Ta)/log(S	0.48318102	0.39033297	0.46167644	-0.4439656	0.76470861	0.22194804	0.56205712	0.45178527	0.99054212	0.92044381	1	
(Ts-Ta)/ln(SR	0.48321723	0.39035766	0.46170886	-0.4439885	0.76478704	0.22207866	0.56220618	0.45186774	0.99053247	0.92047535	0.99999997	1
LST (˚C)	0.22775089	0.09159102	0.02133124	-0.664693	0.75934273	0.73420727	0.76821513	0.83767455	0.45367888	0.38031662	0.44077586	0.44083152
LST-Ta	0.42822054	0.29991918	0.24911951	-0.8076031	0.38415077	0.15853411	0.37057029	0.40186298	0.44908581	0.38296951	0.43979283	0.43975503
(LST-Ta)/SR	0.1201874	0.24495029	0.26438358	0.31570427	-0.6813769	-0.6912758	-0.8085353	-0.5902965	-0.373627	-0.2180043	-0.343078	-0.3432137
(LST-Ta)/log(	0.40677073	0.35537061	0.31809289	-0.5384692	-0.0263638	-0.2047414	-0.0930924	0.04962043	0.16911412	0.18859883	0.17525081	0.17515275
(LST-Ta)/ln(S	0.40686991	0.35548254	0.31817114	-0.5384667	-0.0263703	-0.2046567	-0.0931181	0.04970285	0.16901658	0.18861457	0.17518083	0.17508277
(Ts-Ta)*log(S	0.3007878	0.19394216	0.2765105	-0.4304174	0.78348204	0.24574965	0.58453192	0.47956709	0.99593195	0.81050807	0.97440742	0.97439382
(LST-Ta)*log(	0.40672935	0.25229684	0.20379611	-0.860897	0.60580916	0.35902105	0.61770459	0.56720081	0.59578599	0.4873274	0.57950607	0.57950871
LST*SR	0.16011189	0.04330461	0.01852919	-0.4905807	0.90211619	0.80757412	0.96450215	0.83812543	0.60568749	0.48776097	0.58551179	0.58562536
LST/SR	0.15502186	0.11443052	0.05313503	-0.3309876	0.06515856	0.21260596	0.00681296	0.32762755	-0.115361	-0.0435094	-0.1052228	-0.1052574
LST/Ta	-0.1331769	-0.1050904	-0.2318569	0.02804942	-0.0787414	0.46426674	0.00799666	0.28188354	-0.6043757	-0.4419897	-0.5811031	-0.5810629
(Ts-Ta)/sqrt(	0.54101492	0.45441009	0.52078619	-0.4422671	0.7490563	0.2113534	0.54771395	0.43557865	0.97650868	0.94793323	0.99680672	0.99681165
(LST-Ta)/sqrt	0.32249387	0.32254146	0.29670904	-0.3045464	-0.2902105	-0.3990782	-0.3728092	-0.1726473	-0.0512044	0.01627249	-0.0377508	-0.0378713

	LST (˚C)	LST-Ta	(LST-Ta)/SR	(LST-Ta)/log(SR	(LST-Ta)/ln(SR	(Ts-Ta)*log(SR	(LST-Ta)*log(SR	LST*SR	LST/SR	LST/Ta	(Ts-Ta)/sqrt(SR	(LST-Ta)/sqrt(SR
LST (˚C)	1											
LST-Ta	0.78673596	1										
(LST-Ta)/SR	-0.4051	0.03947585	1									
(LST-Ta)/log(	0.47084225	0.87091515	0.52261575	1								
(LST-Ta)/ln(S	0.47087611	0.8708874	0.52265329	0.99999995	1							
(Ts-Ta)*log(S	0.46724412	0.45663083	-0.3889238	0.16879945	0.16868515	1						
(LST-Ta)*log(	0.87880012	0.95161751	-0.2549434	0.68083374	0.68078676	0.60621671	1					
LST*SR	0.83798765	0.48452368	-0.6758724	0.06264736	0.06260197	0.62236777	0.69974118	1				
LST/SR	0.60628314	0.68836134	0.38169206	0.79117078	0.79129187	-0.1115579	0.51920861	0.12474064	1			
LST/Ta	0.293584	0.00438061	0.03748125	0.04673041	0.04695497	-0.6083115	-0.0496784	0.01770847	0.55944565	1		
(Ts-Ta)/sqrt(	0.42452609	0.42579088	-0.3252227	0.17181711	0.17176342	0.95337922	0.56124162	0.5654098	-0.105281	-0.5648921	1	
(LST-Ta)/sqrt	0.21664152	0.67791983	0.75155572	0.95106837	0.95108859	-0.0550795	0.42169887	-0.2161729	0.76781738	0.08755333	-0.0348958	1

Markovian state representation of the phenological stages





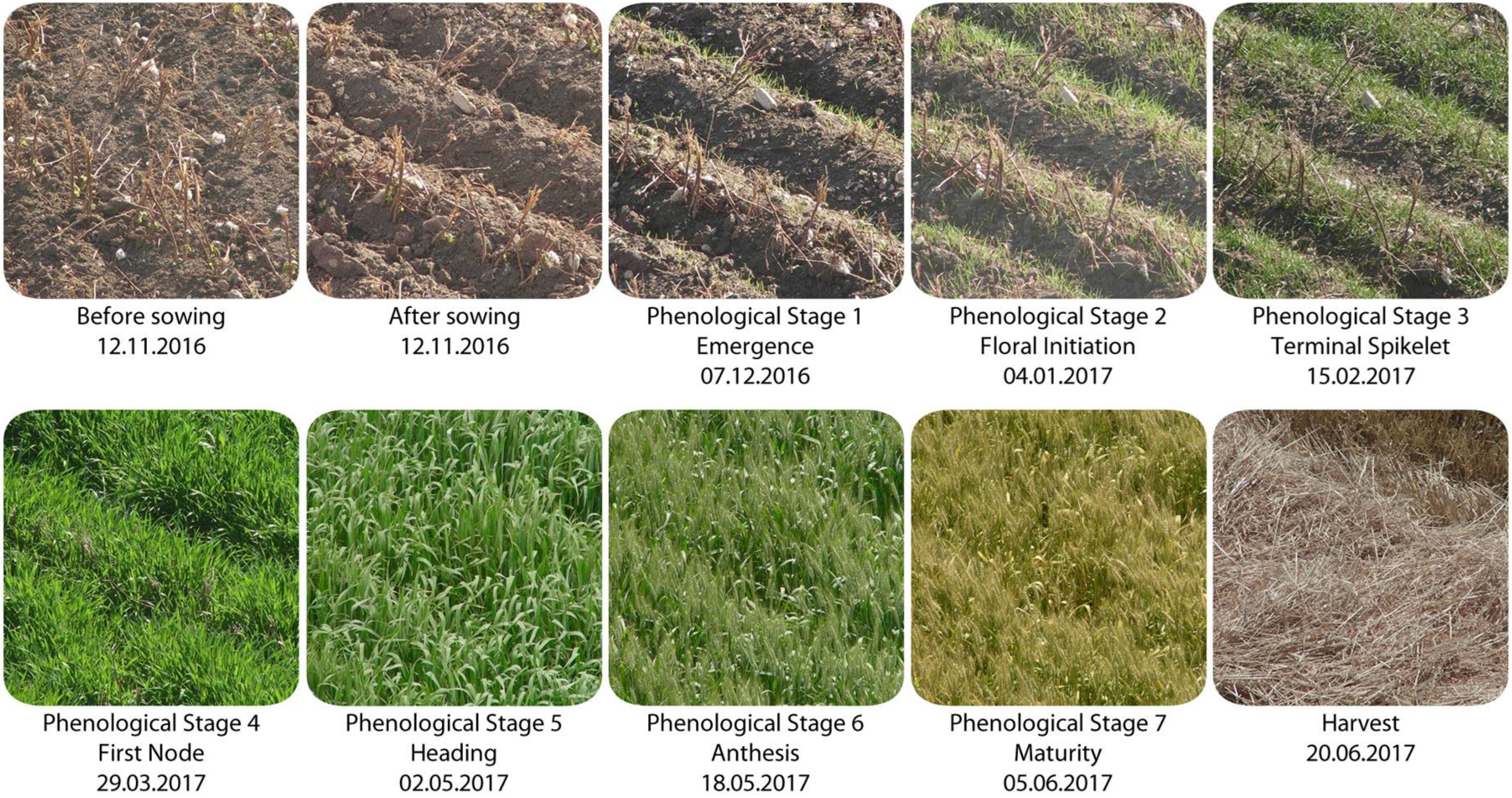


$O(x,n)=f_x(I(n),I(n-1),\dots I(0))$

$O(y,n)=f_y(I(n),I(n-1),\dots I(0))$

$S_x \rightarrow S_y : \Phi_{xy}(I(n),I(n-1),\dots I(0))$

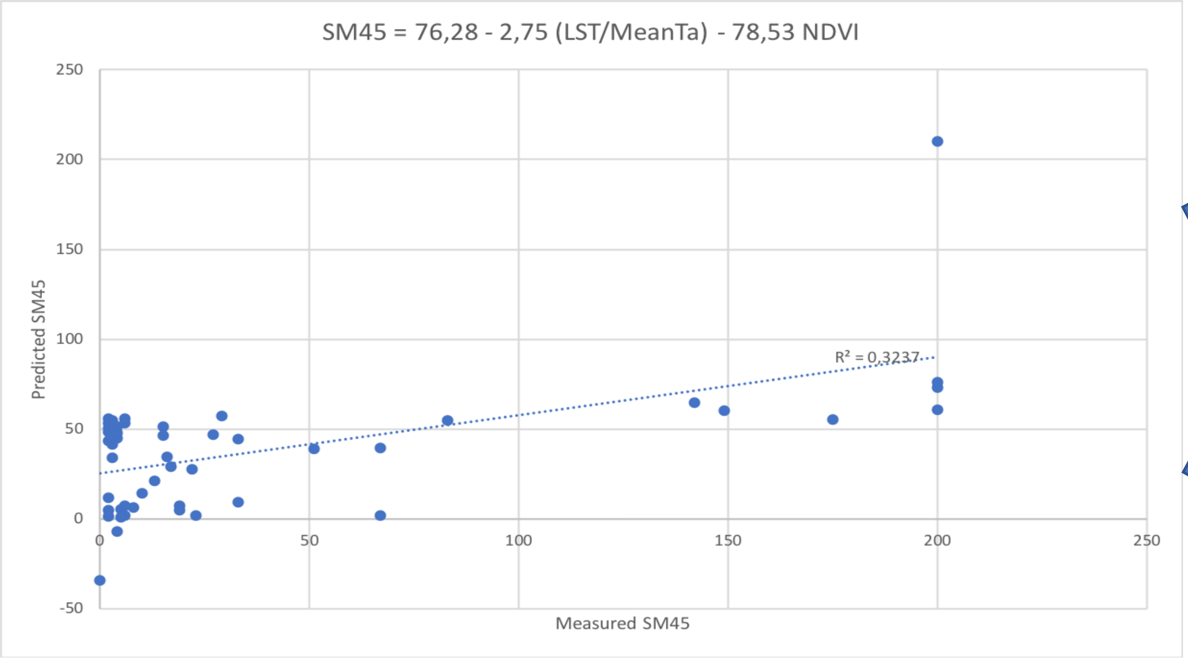
Phenological stages can both be observed and nowcasted depending on monitoring schedule of the Digital Twinning system

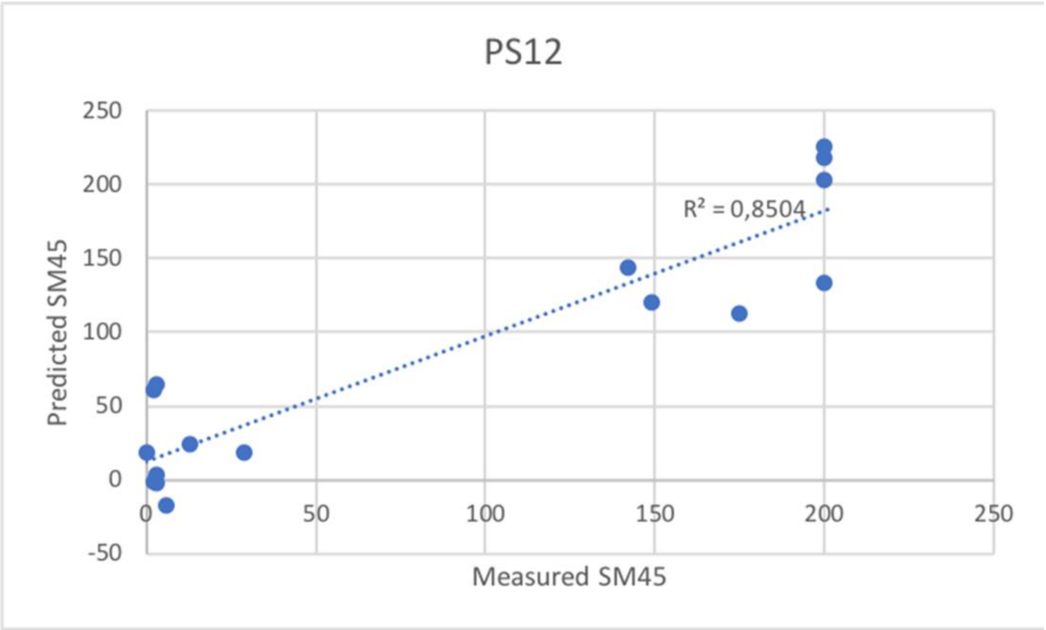

Before sowing
12.11.2016
After sowing
12.11.2016
Phenological Stage 1
Emergence
07.12.2016
Phenological Stage 2
Floral Initiation
04.01.2017
Phenological Stage 3
Terminal Spikelet
15.02.2017
Phenological Stage 4
First Node
29.03.2017
Phenological Stage 5
Heading
02.05.2017
Phenological Stage 6
Anthesis
18.05.2017
Phenological Stage 7
Maturity
05.06.2017
Harvest
20.06.2017

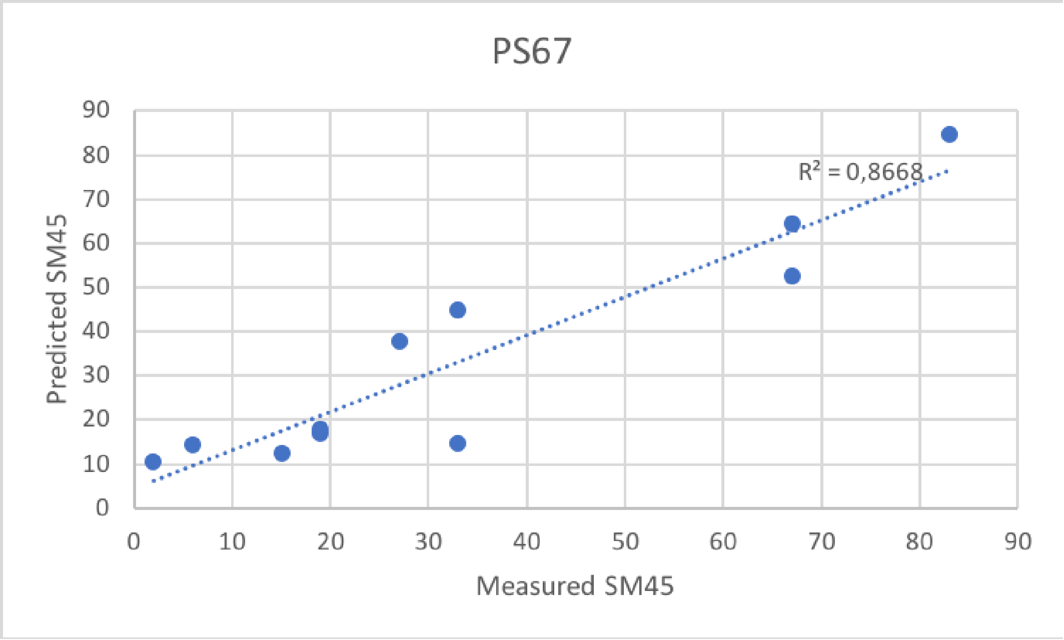
Correlation to the root zone soil moisture

2- ROLE of DATA SEGMENTATION

Without phenological stage segmentation:
Two highest correlating parameters R^2=0.3237







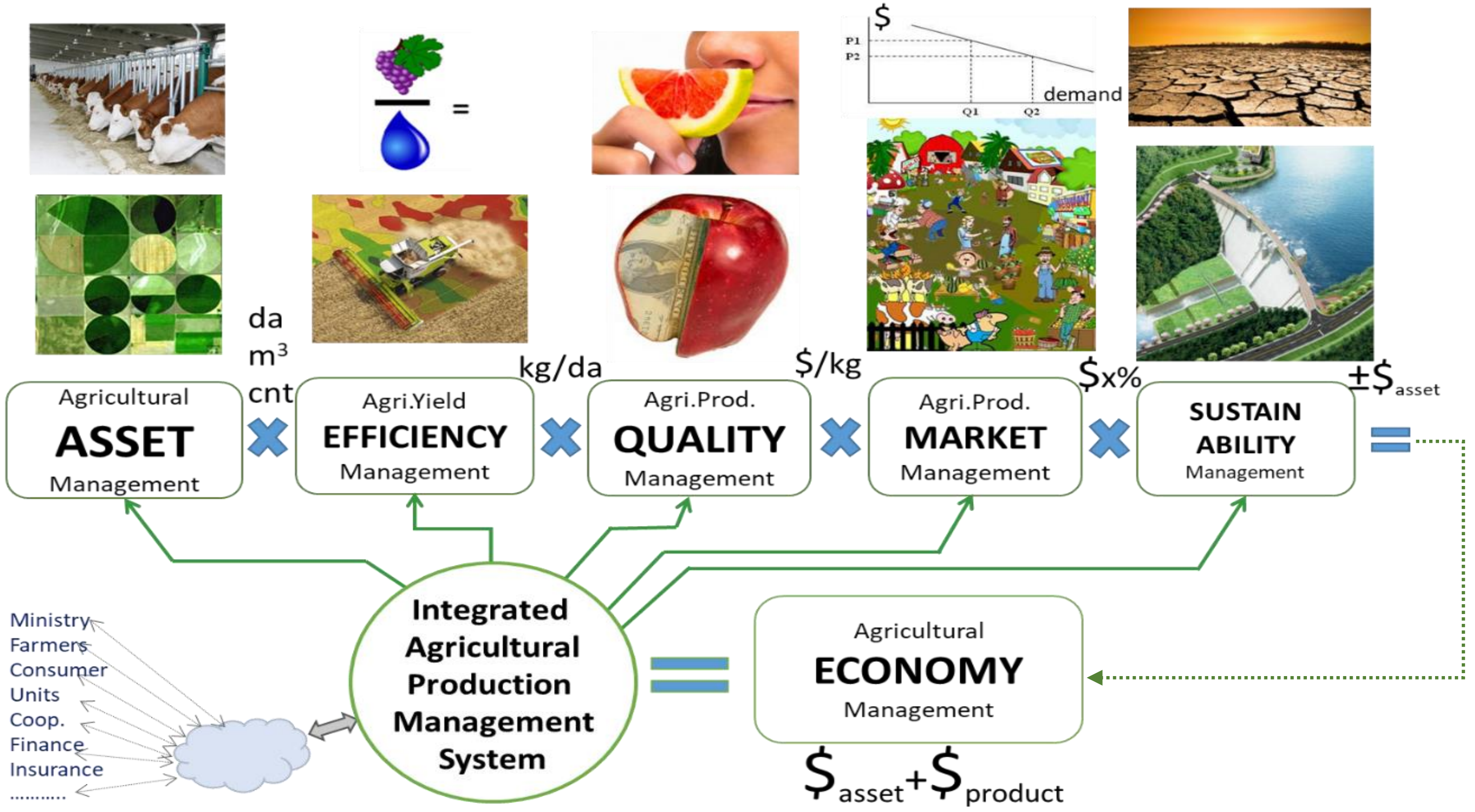
Potential of increasing the efficiency in a sustainable way:

Convergence through Digital Twinning

1- Integrated Agricultural Production and Food Supply Chain Management

2- Precision Agriculture

3- Novel production technologies (vertical farming, indoor farming ….)



Digital Twinning in Crop Production

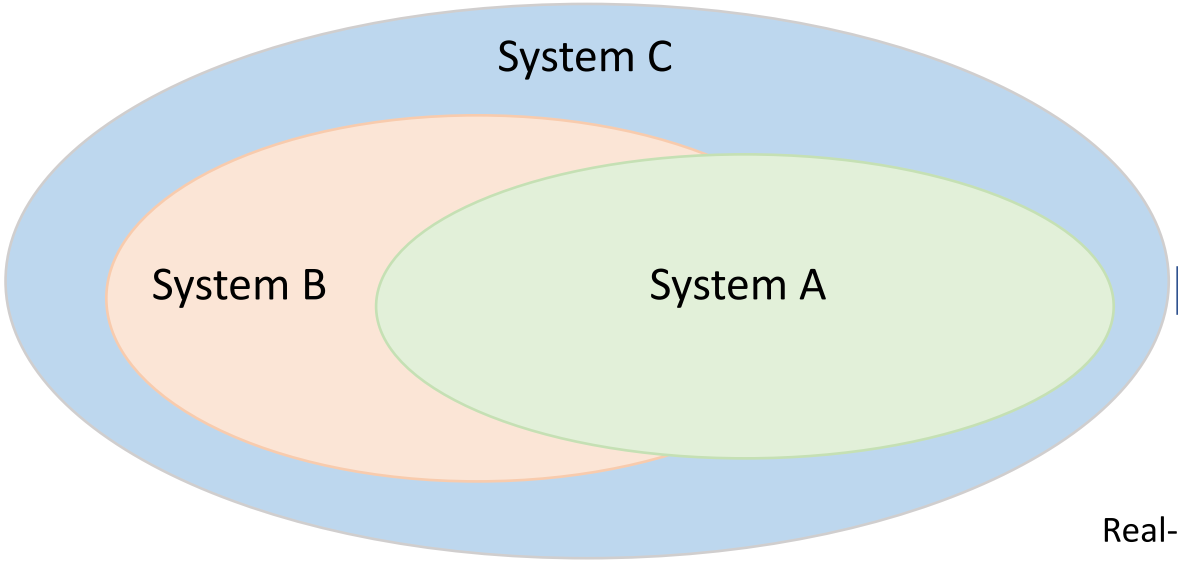
System A: Plant system: Non-linear time varying in interaction with soil and the atmosphere (time constant is in days range if we neglect variety development)

System B: Non-linear time varying soil structure (time constant is around year range)

System C: Climate and Ecology (Chaotic and Stochastic) (time constant is in decade range)

System D: Cropping system: Rule-based, adaptive

Greenhouse agriculture and indoor farming systems differs from field conditions for digital twinning strategies



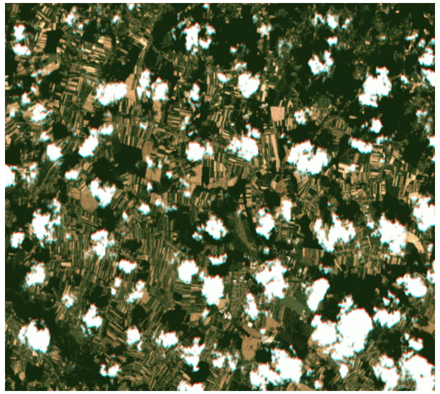
High amount of parameters with huge amount of data requirement for optimal decision making.

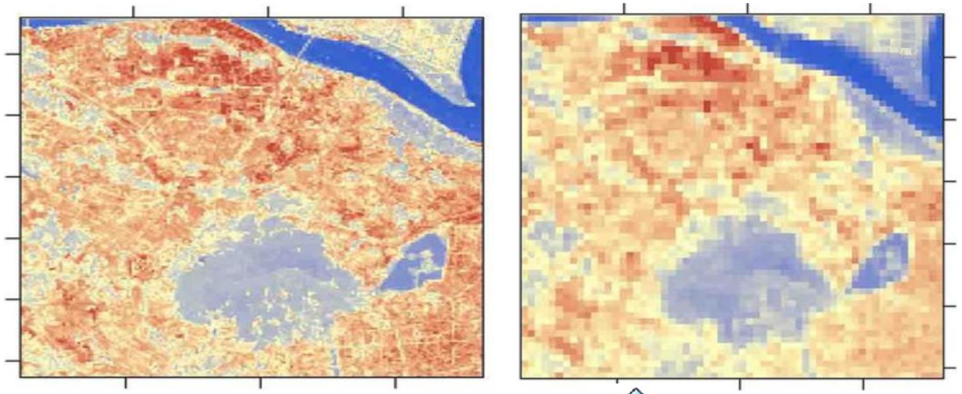
Simplification
Harmonization
Coordination
Reference network
PaaS
DaaS
Data driven models
QoS management
AIaaS

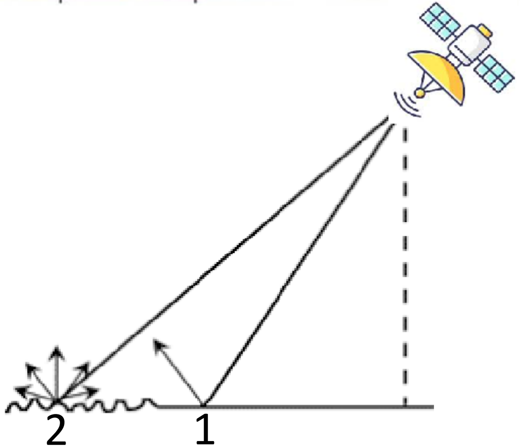
Real-time twinning concerns:
Clean Data Availability
Accuracy Management
Scalability of the models

Real-time Continuous Monitoring

→ Real-time Diagnostics, Reconstruction, Fusion, Super resolution







<u>Remote sensing problems:</u>

Cloudiness
Surface disturbance / Snow coverage
Resolution differences
Viewing and altitude

<u>Insitu monitoring problems:</u>

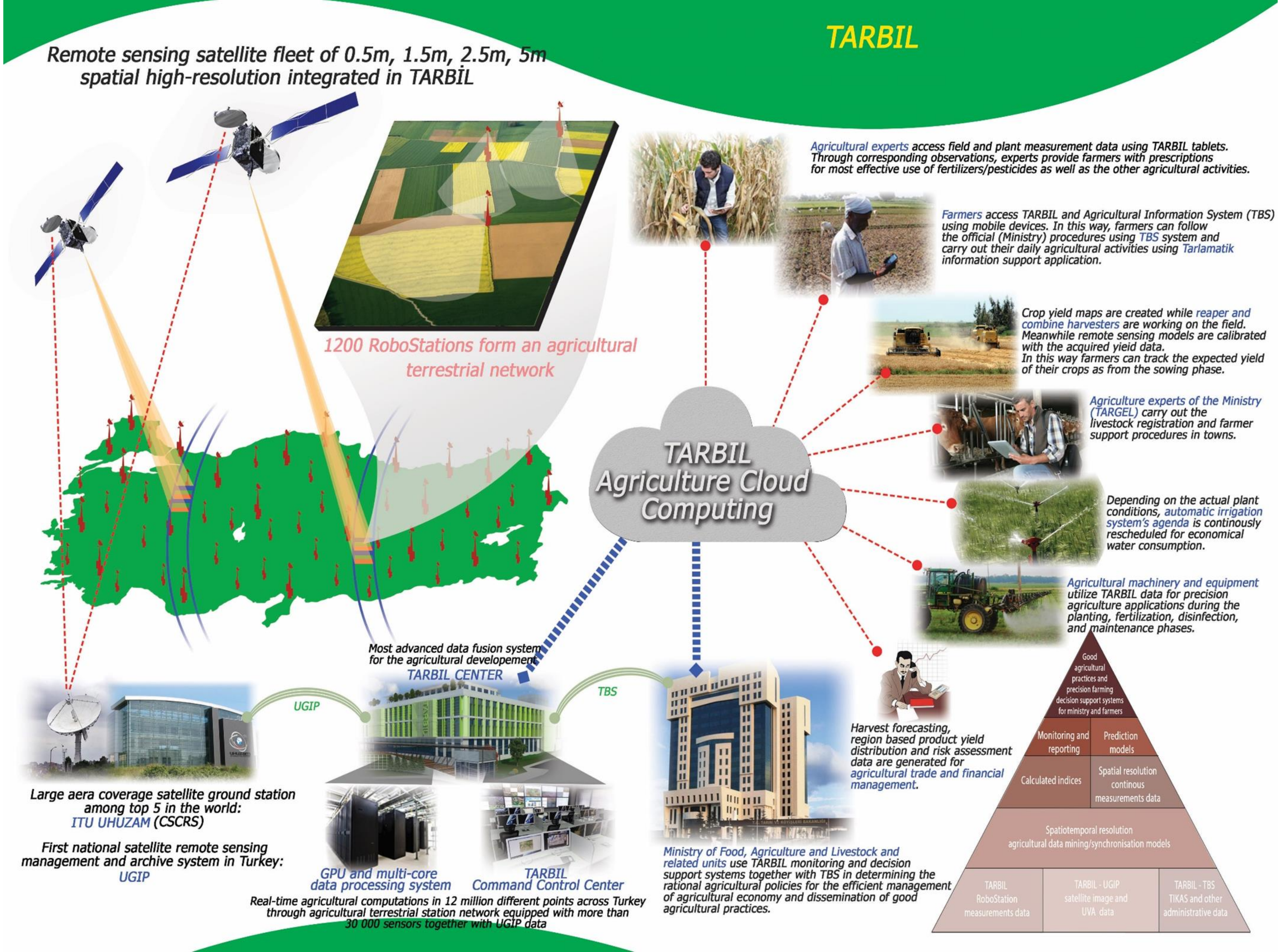
Calibration requirement
Sensor maintenance
Disturbances
Interruptions (Communication, maintenance, energy…)
Temporal data is available at specific monitoring locations
Distribution of the locations are non-uniform
Multi-temporal / spatial data is available at some predefined instants

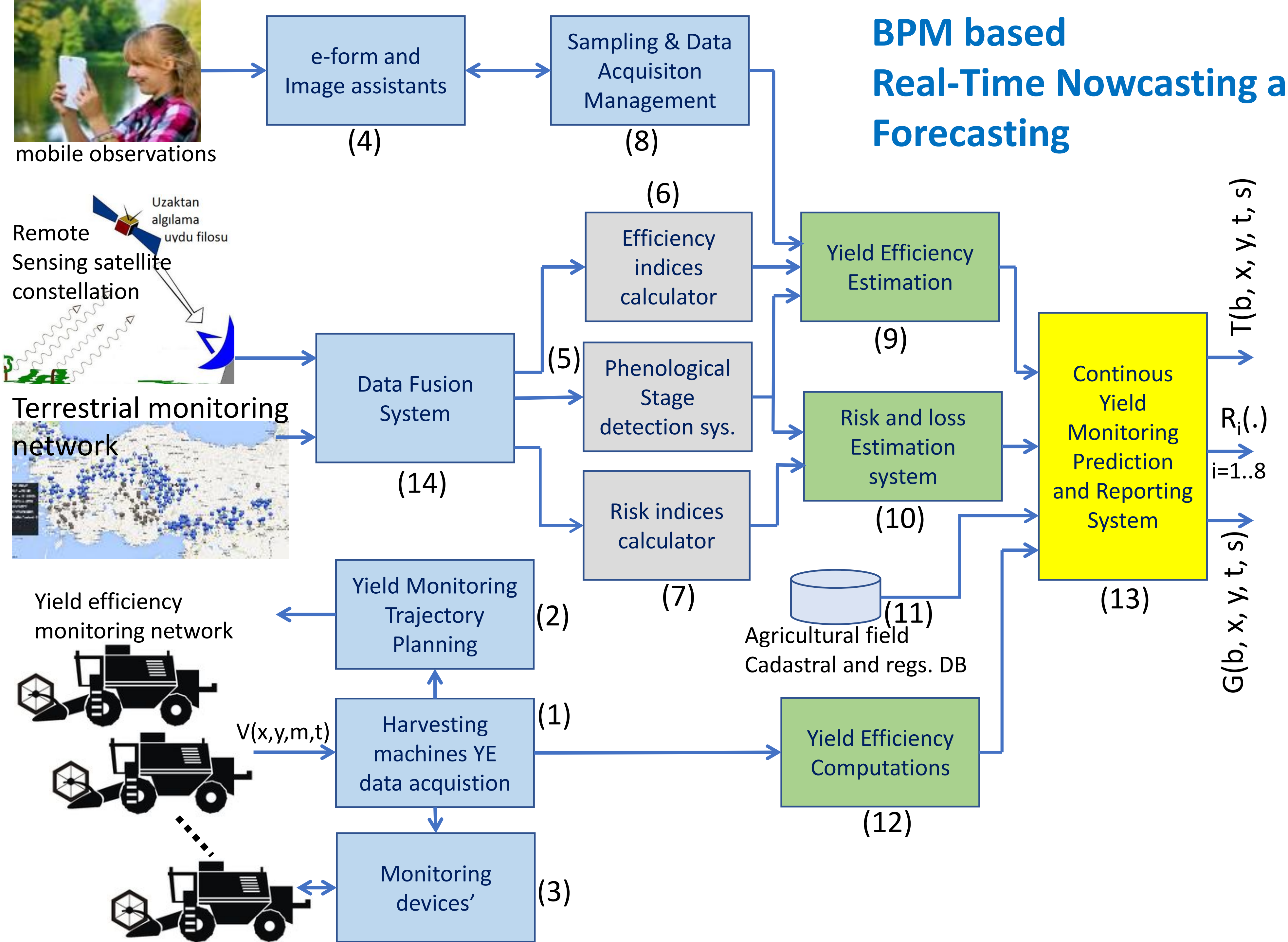
<u>Sampling & Resolution differences:</u>

Temporal data is available at specific monitoring locations
Distribution of the locations are non-uniform
Multi-temporal / spatial data is available at some predefined instants

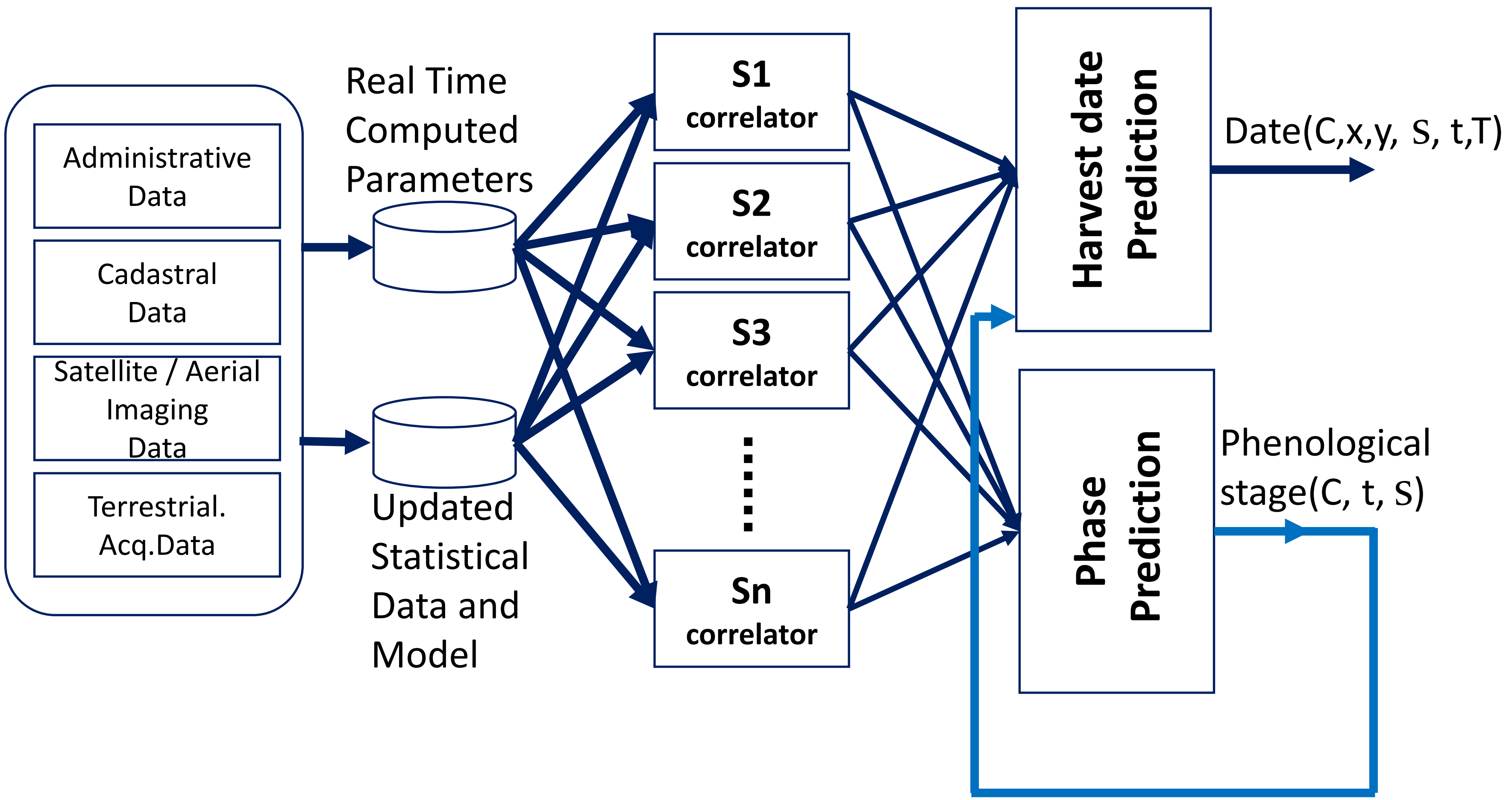
<u>Farm registry problems:</u>

Human data entry failures
Statistical sampling problems
Farmers may not share data
Data resource discontinuity

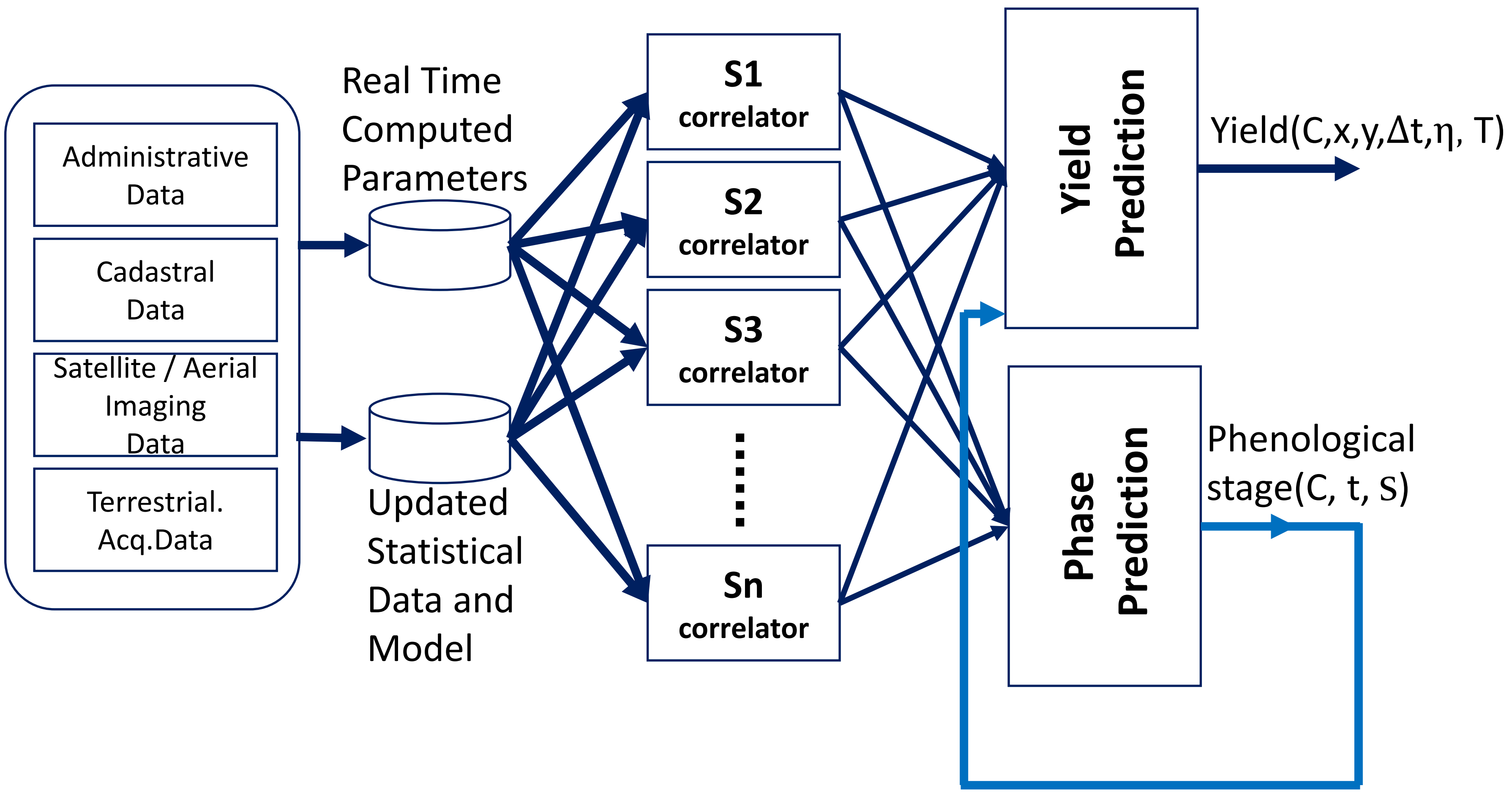

TARBIL
Remote sensing satellite fleet of 0.5m, 1.5m, 2.5m, 5m spatial high-resolution integrated in TARBİL
1200 RoboStations form an agricultural terrestrial network
Agricultural experts access field and plant measurement data using TARBIL tablets. Through corresponding observations, experts provide farmers with prescriptions for most effective use of fertilizers/pesticides as well as the other agricultural activities.
Farmers access TARBIL and Agricultural Information System (TBS) using mobile devices. In this way, farmers can follow the official (Ministry) procedures using TBS system and carry out their daily agricultural activities using Tarlamatik information support application.
Crop yield maps are created while reaper and combine harvesters are working on the field. Meanwhile remote sensing models are calibrated with the acquired yield data. In this way farmers can track the expected yield of their crops as from the sowing phase.
Agriculture experts of the Ministry (TARGEL) carry out the livestock registration and farmer support procedures in towns.
TARBIL Agriculture Cloud Computing
Depending on the actual plant conditions, automatic irrigation system's agenda is continously rescheduled for economical water consumption.
Agricultural machinery and equipment utilize TARBIL data for precision agriculture applications during the planting, fertilization, disinfection, and maintenance phases.
Most advanced data fusion system for the agricultural developement
TARBIL CENTER
UGIP
TBS
Harvest forecasting, region based product yield distribution and risk assessment data are generated for agricultural trade and financial management.
Good agricultural practices and precision farming decision support systems for ministry and farmers
Monitoring and reporting
Prediction models
Calculated indices
Spatial resolution continous measurements data
Spatiotemporal resolution agricultural data mining/synchronisation models
TARBIL RoboStation measurements data
TARBIL - UGIP satellite image and UVA data
TARBIL - TBS TIKAS and other administrative data
Large aera coverage satellite ground station among top 5 in the world: ITU UHUZAM (CSCRS)
First national satellite remote sensing management and archive system in Turkey: UGIP
GPU and multi-core data processing system
TARBIL Command Control Center
Real-time agricultural computations in 12 million different points across Turkey through agricultural terrestrial station network equipped with more than 30 000 sensors together with UGIP data
Ministry of Food, Agriculture and Livestock and related units use TARBIL monitoring and decision support systems together with TBS in determining the rational agricultural policies for the efficient management of agricultural economy and dissemination of good agricultural practices.


BPM based
Real-Time Nowcasting and
Forecasting
mobile observations
e-form and
Image assistants
(4)
Sampling & Data
Acquisiton
Management
(8)
Uzaktan
algılama
uydu filosu
Remote
Sensing satellite
constellation
(6)
Efficiency
indices
calculator
Yield Efficiency
Estimation
(9)
T(b, x, y, t, s)
Terrestrial monitoring
network
Data Fusion
System
(14)
(5)
Phenological
Stage
detection sys.
Risk and loss
Estimation
system
(10)
Continous
Yield
Monitoring
Prediction
and Reporting
System
(13)
R_i(.)
i=1..8
G(b, x, y, t, s)
Risk indices
calculator
(7)
(11)
Agricultural field
Cadastral and regs. DB
Yield efficiency
monitoring network
Yield Monitoring
Trajectory
Planning
(2)
V(x,y,m,t)
Harvesting
machines YE
data acquistion
(1)
Yield Efficiency
Computations
(12)
Monitoring
devices'
(3)

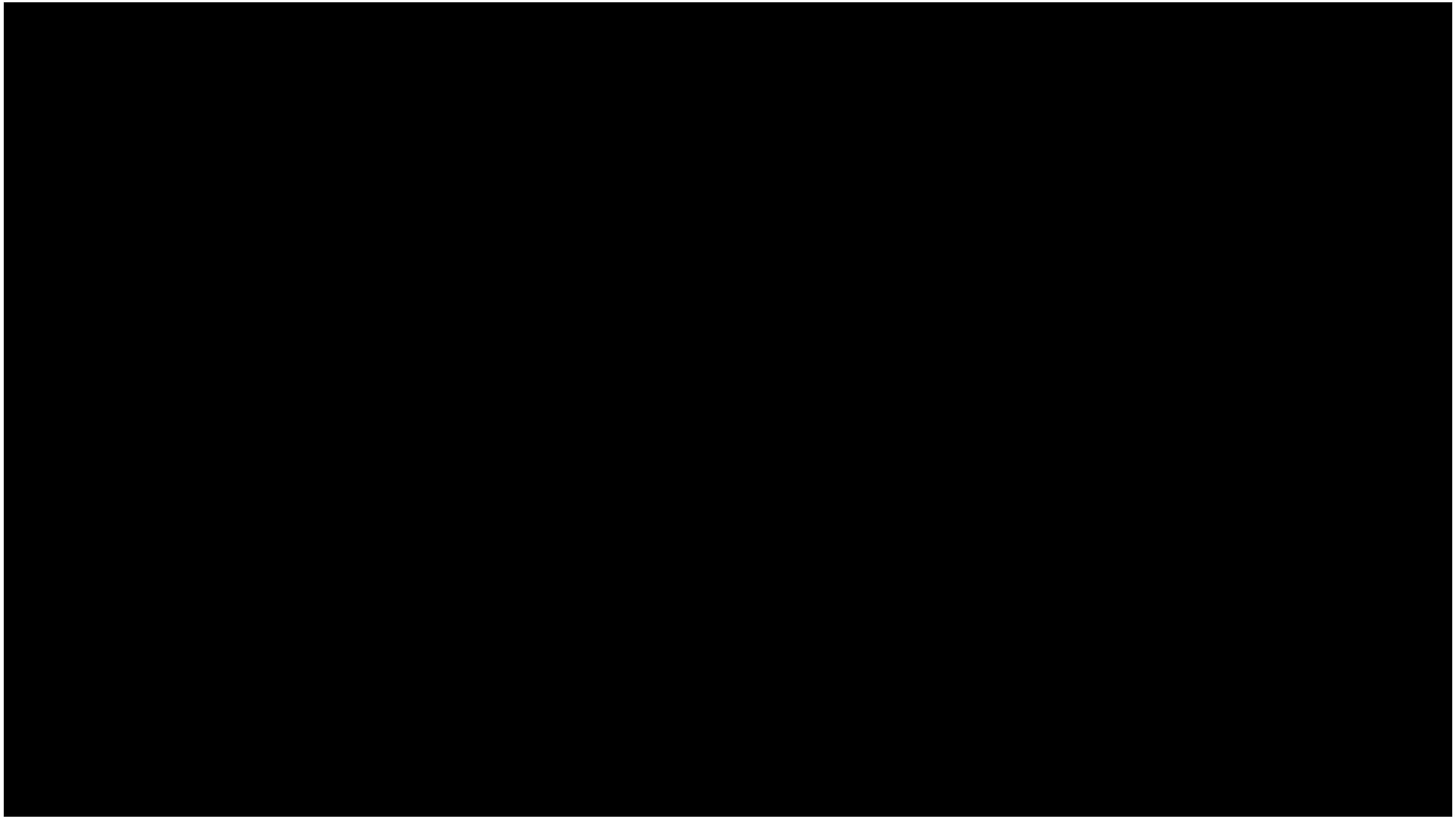
Phenological stage transition date estimation based on finite-state machine model



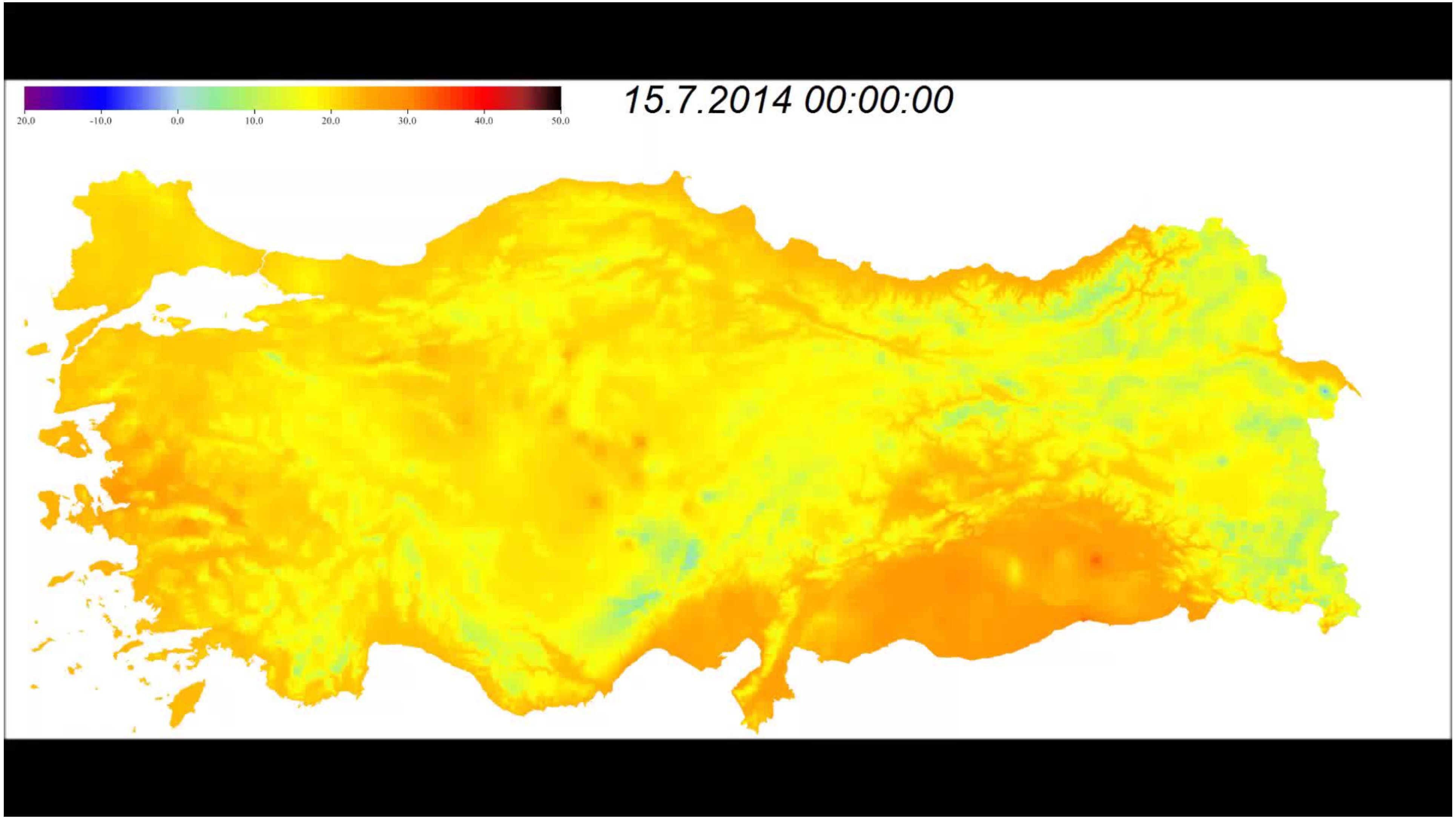
Yield Nowcasting and Forecasting based on finite-state machine model



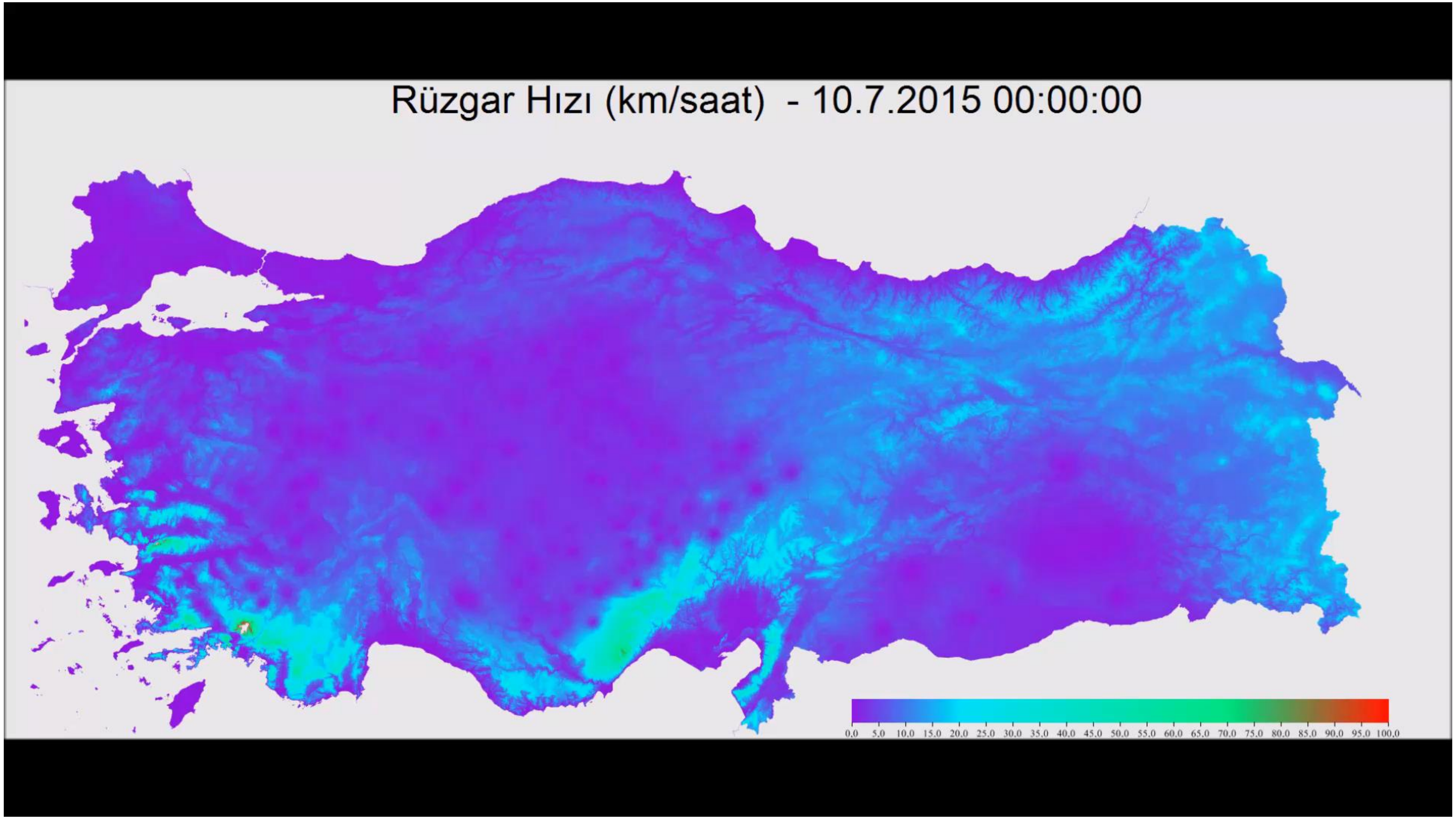
1200stations, 42.000sensors, 10min-30min sampling interval
250mx250m model based interpolations @more than 12Million points 30mins..1day



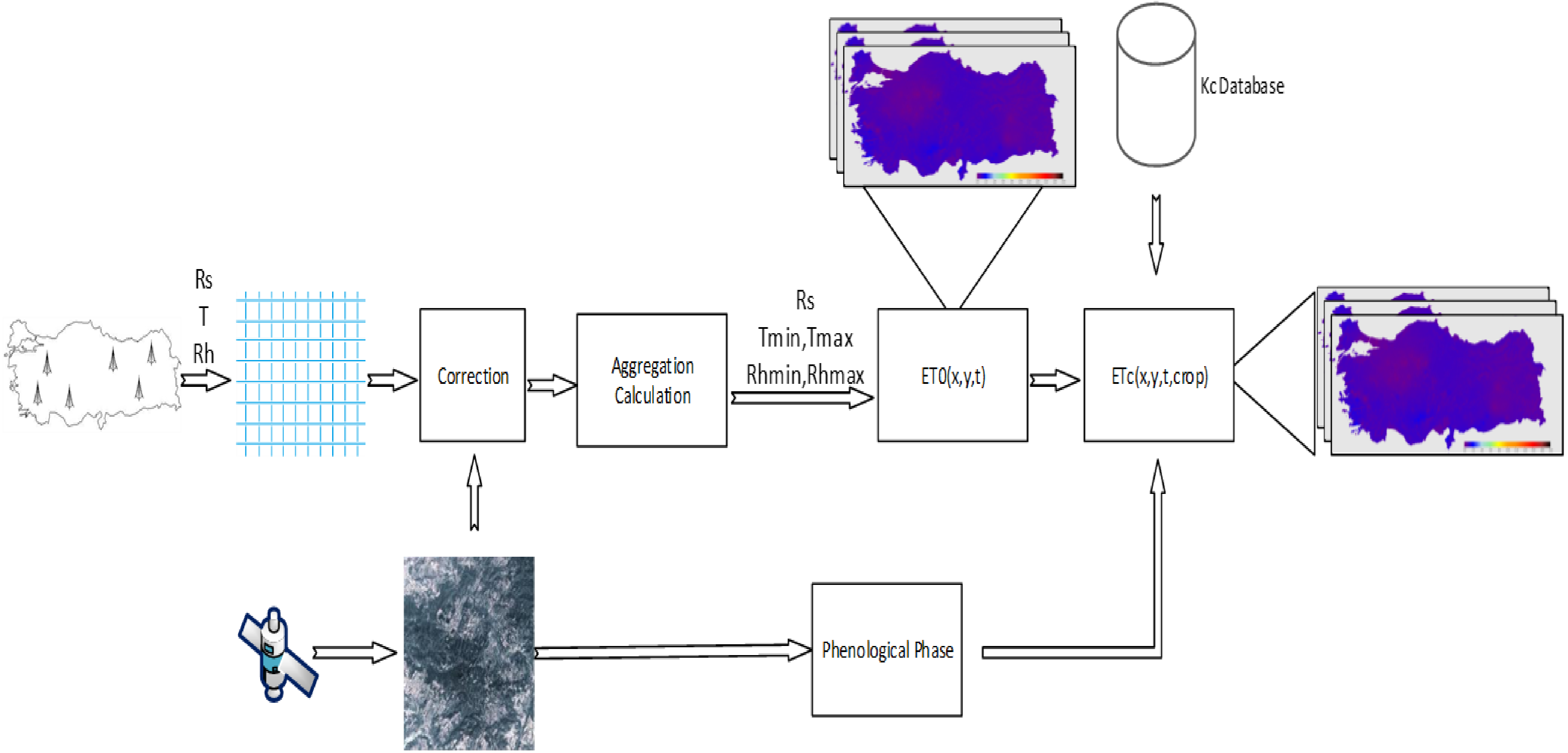
More than 230 parameters are computed at 250m resolution at 30min. time intervals. 35 different data is sampled from each station at 10-30min. intervals



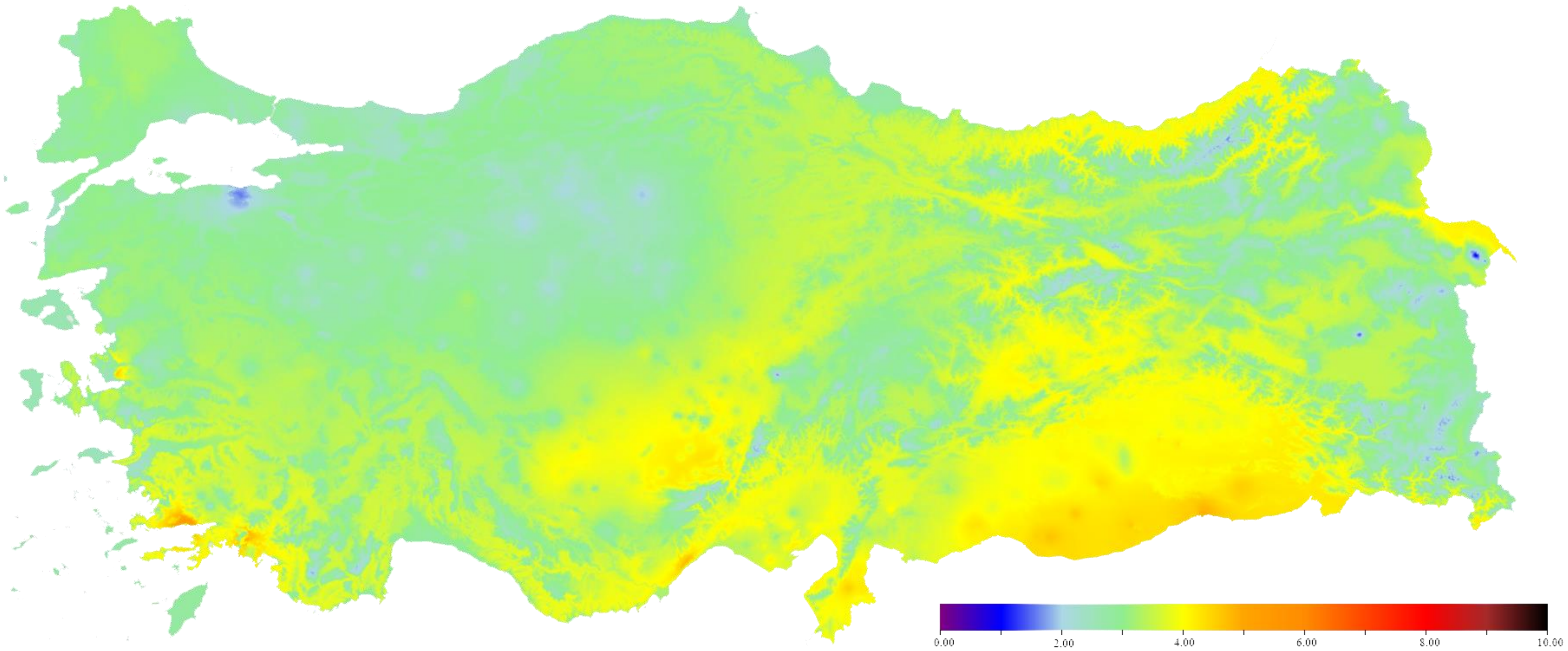
Monitoring of Wind speed over agicultural fields in Real Time



Real Time Spatio Temporal ET Mapping

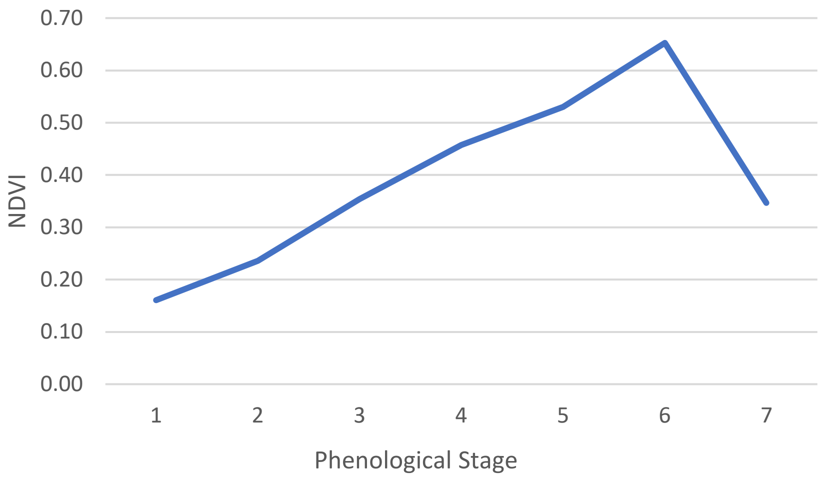


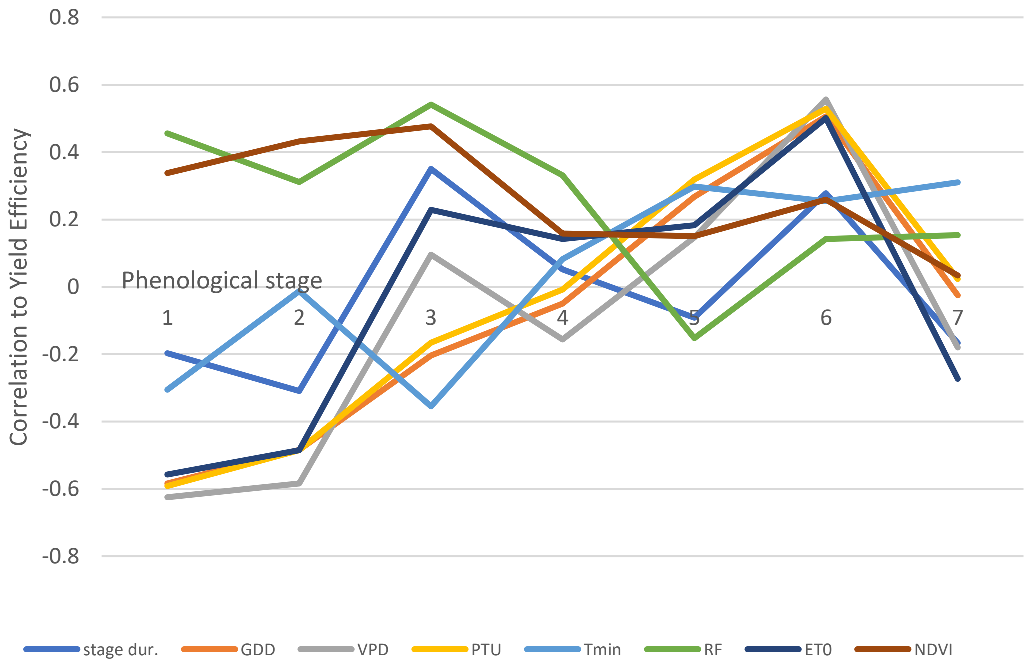
ET0(mm) - 5.4.2015

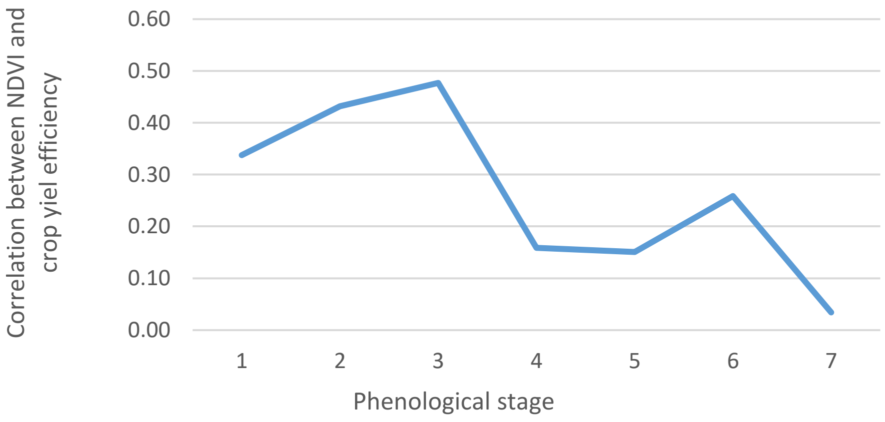


Province	Town	Sowing Date	stage1 (days)	GDD	VPD	PTU	Tmin	RF	PET	NDVI	stage2 (days)	GDD	VPD	PTU	Tmin	RF	PET	NDVI	stage3 (days)	GDD	VPD	PTU	Tmin	RF	PET	NDVI	stage4 (days)	GDD	VPD	PTU	Tmin	RF	PET	NDVI
Sanliurfa	Suruc	10/25/2013	25	285.1	26.11	2931	9.54	22.58	52.47	0.1028	61	193.3	24.9	1870	-2.99	40.94	65.68	0.1351	13	52.5	3.09	524	3.3	33.18	12.41	0.341	53	318.9	31.47	3611	-2	61.04	111.13	0.4439
Sanliurfa	Suruc	10/15/2014	17	200.6	12.09	2149	9.55	34.32	41.2	0.0827	10	73.9	8.45	758	4.58	0.16	21.93	0.1208	12	100.6	7.97	1001	7.07	30.62	23.14	0.2036	23	122.1	5.44	1169	3.96	51.54	21.98	0.3617
Sanliurfa	Merkez	11/16/2012	17	124.8	6.41	1216	5.53	8.68	19.91	0.2665	19	52.6	3.57	499	0.7	37.38	16.19	0.306	25	39.5	6.71	375	-2.18	18.93	24.8	0.3254	33	105.9	7.93	1084	0.8	16.49	40.6	0.3448
Diyarbakir	Yenisehir	11/12/2013	18	123.4	6.26	1205	6.03	11.74	17.36	0.1389	61	38.5	10.18	376	-9.62	47.34	37.31	0.2484	29	95.2	14.74	1023	-4.98	28.64	45.15	0.3065	33	208.1	15.45	2448	-0.38	56.34	70.21	0.3646
Gaziantep	Araban	11/6/2012	13	129.0	6.94	1292	8.2	40.56	20.25	0.1648	19	110.2	5.17	1064	4.49	42.32	17.54	0.204	4	14.0	0.54	132	4.96	16.79	2.98	0.2433	89	219.2	23.63	2275	-2.79	152.55	109.34	0.2562
Gaziantep	Araban	11/22/2011	23	36.3	10.76	348	-1.51	35.38	34.16	0.021	17	29.2	4.61	275	0.2	19.1	16.77	0.0989	39	23.5	7.42	228	-3.3	91.3	37.46	0.1767	49	109.2	21.51	1297	-2.72	147.87	112.55	0.3937
Gaziantep	Nurdagi	11/15/2013	39	238.3	21.64	2314	-1.21	19.54	44.7	0.1713	14	66.4	6.33	630	1.62	16.48	16.62	0.2499	28	152.1	11.11	1501	-0.67	24.76	31.14	0.3944	31	248.5	19.93	2719	-0.21	23.62	59.27	0.4805
Gaziantep	Nurdagi	11/7/2014	31	288.7	20.25	2841	4.84	35.42	51.08	0.1768	20	145.1	7.16	1374	2.77	54.76	23.43	0.22	25	80.9	5.56	778	-2.01	112.96	24.17	0.5147	56	361.1	22.24	3947	1.31	208.42	94.49	0.5929
Gaziantep	Nurdagi	11/19/2011	39	82.1	14.95	788	-1.31	97.46	50.21	0.2001	19	16.9	3.16	162	-0.37	77.48	14.78	0.1928	70	92.9	24.65	1081	-4.52	210.78	129.56	0.4198	21	188.7	15.98	2392	3.34	10.98	76.53	0.6194
Gaziantep	Nurdagi	11/10/2012	22	171.3	8.66	1683	4.85	50.91	25.54	0.2041	10	30.2	1.6	287	2.96	81.3	7.38	0.4044	44	71.9	9.7	692	-3.04	128.44	36.47	0.6046	36	159.1	10.7	1693	1.25	129.3	46.08	0.6267
Mardin	Kiziltepe	11/28/2011	29	53.0	12.82	502	-0.71	39.78	45.08	0.1413	17	24.4	4.95	232	0.87	134.7	21.3	0.1824	33	16.0	8.12	163	-5.24	104.82	42.97	0.2236	38	82.9	18.76	971	-2.02	57.91	102.64	0.2947
Mardin	Kiziltepe	12/5/2012	21	56.1	4.35	531	-0.35	44.66	21.95	0.1482	15	15.2	4.62	145	-1.67	33.89	17.16	0.2545	25	50.0	6.36	500	-3.8	50.53	30.46	0.3608	31	110.5	9.69	1197	0.43	42.97	53.45	0.2157
Gaziantep	Oguzeli	11/16/2011	15	43.0	5.67	423	-1.51	39.24	20.43	0.1924	14	16.5	5.83	157	-1.36	28.42	18.28	0.2528	47	48.2	9.46	460	-4.09	147.88	42.04	0.4632	43	32.0	13.59	360	-3.23	121.18	72.09	0.6175
Gaziantep	Oguzeli	12/1/2012	19	46.3	3.5	442	-1.54	79.08	14.44	0.1508	14	33.1	3.34	314	0.04	32.04	11.3	0.2626	31	47.2	6.6	471	-2.97	84.35	30.39	0.3687	40	189.1	15.69	2091	0.34	90.49	76.1	0.4573
Gaziantep	Oguzeli	11/19/2014	22	129.2	5.78	1248	3.9	68.5	21.44	0.1402	17	64.4	3.32	611	2.29	17.76	13.39	0.1766	33	66.9	6.22	652	-3.73	97.66	28.8	0.4378	76	390.9	25.64	4609	-0.62	189.88	142.47	0.5197
Sanliurfa	Akcakale	12/12/2012	18	41.2	4.3	391	-0.58	21.44	19.03	0.2017	19	7.7	4.9	74	-3.14	30.15	21.5	0.2788	23	83.3	4.68	850	1.59	16.42	26.93	0.2827	23	80.1	7.96	881	0.27	44.14	44.77	0.4431
Sanliurfa	Akcakale	11/11/2013	40	193.4	18	1904	-3.75	19.76	51.21	0.1292	22	53.3	9.83	509	1.09	17	26.34	0.1501	36	112.5	14.41	1146	-2.89	24.24	51.48	0.1796	20	163.0	12.76	1818	3.89	45.98	48.52	0.3974
Sanliurfa	Siverek	11/14/2012	13	107.2	5.29	1048	7.91	2.96	15.66	0.143	18	74.2	4.16	706	3.63	24.73	15.39	0.2166	26	44.4	6.1	419	-0.03	22.76	21.66	0.4783	56	155.9	15.04	1642	-2.86	30.89	75.14	0.5046
Sanliurfa	Ceylanpin	11/10/2014	19	143.1	12.09	1420	4.68	48.46	40	0.1284	6	27.5	1.34	264	4.95	0.86	5.13	0.1585	11	76.4	3.88	726	6.28	23.6	15.65	0.356	75	203.6	21.95	2068	-2.98	114.16	101.78	0.5374
Sanliurfa	Ceylanpin	10/25/2013	25	304.1	28.61	3123	10.07	23.94	60.74	0.1348	25	111.5	11	1084	-2.97	23.14	34.32	0.2153	27	66.6	13.71	635	-1.13	11.92	37.32	0.3801	39	143.9	18.5	1479	-2.62	29.26	65.35	0.5464
Sanliurfa	Merkez	11/19/2011	20	38.6	9.7	376	-2.55	10.46	30.25	0.1853	25	48.2	7.8	456	0.85	42.56	28.46	0.2888	39	28.0	8.38	273	-3.51	73.76	42.76	0.3655	48	108.2	22.04	1278	-1.91	122.44	117.59	0.416
Sanliurfa	Akcakale	11/18/2014	12	58.8	3.48	577	3.92	40.96	13.18	0.1049	12	76.4	3.06	731	3.68	17.06	13.52	0.2093	18	57.0	3.62	541	1.91	18.4	15.28	0.2355	66	157.6	16.94	1641	-3.98	112.22	85.87	0.5015
Sanliurfa	Akcakale	11/1/2011	11	55.5	5.99	570	-0.21	21.3	20.72	0.2203	16	61.2	6.65	606	-2.77	16.8	26.23	0.3607	45	80.7	15.62	770	-1.93	46.82	55.5	0.4055	45	26.8	12.05	280	-4.52	103.26	65.59	0.4503
Sanliurfa	Eyyubiye	10/10/2013	41	515.8	54.27	5448	9.44	22.68	107.53	0.0833	58	173.2	23.31	1673	-3.32	45.26	63.56	0.1804	17	63.8	5.23	636	1.1	34.26	19.18	0.2776	33	172.7	18.5	1890	-2.18	20.1	60.84	0.3962
Sanliurfa	Eyyubiye	11/7/2014	14	124.4	11.49	1247	6.36	6.98	29.31	0.1304	8	33.2	1.86	323	4.42	46.32	7.75	0.1635	9	47.3	2.18	453	3.39	0.92	8.06	0.2193	81	214.4	18.15	2116	-3.48	186.48	85.14	0.4814
Diyarbakir	Sur	1/22/2014	20	24.6	6.68	247	-5.83	22.06	22.04	0.2266	15	72.8	8.44	786	0.89	17.16	24.03	0.258	20	116.9	6.88	1337	2.61	55.9	32.78	0.2894	12	88.1	7.31	1066	-0.46	1.7	30.4	0.4248
Diyarbakir	Bismil	11/16/2011	45	63.2	16.22	609	-2.9	83.96	53.67	0.3225	37	16.2	6.81	155	-5.04	112.64	34.15	0.4573	44	41.9	16.07	482	-2.42	87.02	87.15	0.5297	16	99.1	10.05	1230	2.06	20.42	50.3	0.5684
Diyarbakir	Bismil	11/26/2013	50	32.8	7.69	314	-10.14	35.24	28.35	0.0134	33	54.9	11.83	559	-5.28	26.44	37.11	0.3486	12	65.5	6.28	714	2.26	15.9	20.8	0.4898	17	107.7	6.28	1235	3.14	49.56	29.42	0.6142
Diyarbakir	Bismil	12/8/2012	27	45.0	6.48	422	-1.08	86.1	24.48	0.3534	30	40.5	5.83	401	-6	124.56	27.12	0.3601	25	71.3	6.39	760	0.62	62.34	32.17	0.4242	29	151.6	15.2	1778	0.26	20.33	75.55	0.5181
Sanliurfa	Hilvan	11/27/2011	29	51.3	11.37	485	-2.97	9.2	33.86	0.1497	19	26.7	4.33	254	0.82	11.7	17.92	0.2066	56	37.0	15.22	394	-3.51	135.4	82.77	0.3378	25	115.3	15.39	1402	-1.79	54.6	79.34	0.3863
Sanliurfa	Hilvan	12/9/2014	19	73.3	4.34	691	2.1	36.22	16.89	0.1485	15	31.8	2.18	301	-3.58	61.22	11.98	0.1575	29	71.7	8.75	725	-2.31	39.94	36.26	0.331	41	150.8	13.16	1721	0.04	95.68	69.71	0.3979
		Average:	24.02	126.8	11.44	1274	1.88	35.24	34.00	0.16	22.20	58.6	6.27	572	-0.29	40.41	23.02	0.24	27.44	62.9	7.88	642	-0.78	51.41	33.98	0.35	43.00	157.9	15.49	1758	-0.71	76.80	74.49	0.46
		Std.Dev.:	9.51	106.9	9.35	1118	4.51	26.03	19.12	0.07	12.89	42.5	4.82	412	3.12	35.44	13.12	0.08	13.13	32.9	4.84	349	2.72	46.13	22.84	0.11	20.03	81.6	5.98	930	2.22	51.64	27.77	0.11

Province	Town	Sowing Date	stage5 (days)	GDD	VPD	PTU	Tmin	RF	PET	NDVI	stage6 (days)	GDD	VPD	PTU	Tmin	RF	PET	NDVI	stage7 (days)	GDD	VPD	PTU	Tmin	RF	PET	NDVI	Total Duration	Total GDD	Total VPD	Total PTU	Over all Tmin	Total RF	Total PET	NDVI	Yield Eff. (kg/da)
Sanliurfa	Suruc	10/25/2013	20	184.6	17.1	2323	1.73	6.02	70.63	0.4954	8	99.1	6.07	1298	11.71	14.74	28.36	0.5468	17	257.4	23.59	3488	10.03	1.76	95.57	0.2382	197	1390.9	132.33	16045	-2.99	180.26	436.25	2.3032	38
Sanliurfa	Suruc	10/15/2014	71	159.0	15.87	1580	-3.6	161.6	72.82	0.4704	18	97.5	7.94	1110	1.72	24.04	37.34	0.5791	29	184.1	11.46	2275	2.51	72	69.9	0.4785	180	937.7	69.22	10042	-3.6	374.28	288.31	2.2969	171
Sanliurfa	Merkez	11/16/2012	44	278.1	25.21	3288	1.34	41.14	118.45	0.3836	19	194.8	13.03	2510	7.24	20.54	62.12	0.4612	21	325.2	29.4	4439	9.59	37.14	100.72	0.2624	178	1120.8	92.26	13410	-2.18	180.3	382.79	2.35	144
Diyarbakir	Yenisehir	11/12/2013	19	184.6	11.81	2381	5.11	34.9	58.24	0.4111	18	260.5	20.32	3548	8.67	14.04	88.73	0.7469	19	298.7	24.73	4248	9.13	9.06	97.6	0.3136	197	1208.9	103.49	15229	-9.62	202.06	414.6	2.5301	271
Gaziantep	Araban	11/6/2012	34	296.9	23.75	3660	1.85	11.44	105.63	0.5494	25	327.3	29.73	4407	7.42	23.48	104.94	0.8427	23	364.4	28.58	5163	11.39	41.94	107.98	0.5972	207	1461.0	118.34	17992	-2.79	329.08	468.66	2.8575	284
Gaziantep	Araban	11/22/2011	30	362.8	30.66	4742	7.03	24.66	130.91	0.4348	21	329.0	22.66	4587	11.46	16.95	104.57	0.6663	17	303.1	29.45	4367	13.42	0.28	114.26	0.6459	196	1193.0	127.07	15844	-3.3	335.54	550.68	2.4373	256
Gaziantep	Nurdagi	11/15/2013	39	400.9	28.59	4932	2.31	67.62	116.14	0.5453	16	234.0	13.29	3118	11.63	8.14	63.57	0.7789	29	495.1	25.85	6961	12.61	30.34	139.37	0.254	196	1835.3	126.74	22175	-1.21	190.5	470.81	2.8743	136
Gaziantep	Nurdagi	11/7/2014	49	475.1	28.9	6108	4.58	64.62	146.88	0.686	14	229.2	13.7	3175	12.91	8.28	67.47	0.7791	21	392.1	23.06	5607	13.77	10.66	108.05	0.4563	211	1972.2	120.87	23830	-2.01	495.12	515.57	3.4257	303
Gaziantep	Nurdagi	11/19/2011	18	237.2	17.98	3176	9.73	31.2	79.59	0.7192	18	254.3	15.7	3548	12.65	15.52	83.49	0.819	18	320.8	26.43	4614	12.62	1.26	122.62	0.4922	203	1192.8	118.85	15761	-4.52	444.68	556.78	3.4625	270
Gaziantep	Nurdagi	11/10/2012	41	389.0	28.93	4749	0.59	37.74	121.35	0.6378	15	194.5	14.18	2577	10.64	35.14	59	0.6489	30	521.5	35.37	7280	13.17	34.02	139.84	0.179	198	1537.5	109.14	18961	-3.04	496.85	435.66	3.3055	349
Mardin	Kiziltepe	11/28/2011	30	333.0	29.03	4294	3.12	15.16	136.6	0.4916	10	154.6	12.69	2102	13.12	4.96	52.43	0.6884	20	314.6	26.67	4420	11.7	2.36	112.22	0.15	180	978.2	113.04	12686	-5.24	359.69	513.24	2.172	226
Mardin	Kiziltepe	12/5/2012	43	373.5	29.31	4637	1.01	34.02	139.48	0.4084	16	229.1	22.76	3096	7.23	10.78	80.48	0.8564	19	276.0	18.89	3873	10.17	54	82.28	0.2157	170	1110.4	95.98	13978	-3.8	270.85	425.26	2.4597	292
Gaziantep	Oguzeli	11/16/2011	37	292.8	28.39	3694	-2.29	72.75	133.41	0.4853	11	154.3	13.86	2065	9.49	0.2	55.54	0.57	30	451.9	32.13	6332	12.1	26.77	152.44	0.3949	197	1038.7	108.93	13491	-4.09	436.44	494.23	2.9761	268
Gaziantep	Oguzeli	12/1/2012	39	349.3	25.97	4397	3.23	32.53	121.24	0.5016	14	229.8	24.28	3113	8.97	1.14	73.23	0.5459	25	413.8	32.19	5842	11.66	31.72	121.4	0.3642	182	1308.6	111.57	16669	-2.97	351.35	448.1	2.6509	270
Gaziantep	Oguzeli	11/19/2014	29	306.0	23.09	4129	5.51	22.26	109.27	0.5408	11	185.2	16.42	2601	12.01	4.84	61.03	0.5638	9	150.5	11.81	2146	12.69	1.16	51.68	0.2786	194	1293.1	92.28	15995	-3.73	402.06	428.08	2.6575	310
Sanliurfa	Akcakale	12/12/2012	30	230.2	19.74	2792	0.91	15.24	93.15	0.6035	19	195.6	14.83	2540	6.82	20.12	70.14	0.7674	27	452.3	39.22	6250	11.13	48.5	137.85	0.2004	159	1090.3	95.63	13778	-3.14	196.01	413.37	2.7776	203
Sanliurfa	Akcakale	11/11/2013	29	242.8	23.39	2966	0.06	12.48	98.37	0.4431	14	166.8	11.31	2174	6.69	17.6	53.72	0.4888	27	446.2	44.9	6132	10.82	2.56	182.22	0.3039	188	1377.9	134.6	16650	-3.75	139.62	511.86	2.0919	38
Sanliurfa	Siverek	11/14/2012	50	431.3	35.54	5396	1.22	27.6	156.47	0.5308	20	310.3	26.43	4256	11.46	43.92	93.31	0.7807	19	340.7	31.9	4870	12.26	7.9	105.19	0.2418	202	1464.0	124.46	18337	-2.86	160.76	482.82	2.8958	230
Sanliurfa	Ceylanpin	11/10/2014	42	273.3	20.98	3316	2.17	82.38	111.08	0.5104	17	181.3	14.64	2408	5.24	3	73.51	0.4835	21	328.9	30.53	4576	10.49	6.26	121.91	0.4296	191	1234.0	105.41	14778	-2.98	278.72	469.06	2.6037	160
Sanliurfa	Ceylanpin	10/25/2013	50	392.8	33.7	4665	0.37	62.48	146.16	0.7127	17	227.8	17.47	3000	10.92	14.7	77.89	0.8304	19	305.4	29.64	4209	11.57	5.48	123.91	0.5529	202	1552.0	152.63	18194	-2.97	170.92	545.69	3.3727	89
Sanliurfa	Merkez	11/19/2011	16	177.5	15.18	2261	6.15	9.64	67.83	0.4878	18	259.4	21.38	3477	9.23	19.5	89.28	0.5596	23	357.6	27.01	5023	12.06	6.02	123.27	0.2747	189	1017.3	111.49	13143	-3.51	284.38	499.44	2.5779	223
Sanliurfa	Akcakale	11/18/2014	44	300.5	21.31	3707	2.17	73.34	118.74	0.6345	13	137.3	11.27	1838	5.13	6.18	55.27	0.7674	23	369.0	34.83	5151	11.64	6	132.78	0.2004	188	1156.5	94.51	14185	-3.98	274.16	434.64	2.6535	160
Sanliurfa	Akcakale	11/1/2011	43	217.9	27.27	2688	-2.69	64.7	137.26	0.4464	18	233.4	20.83	3084	7.2	14.53	92.92	0.656	24	387.3	30.29	5386	11.72	13.17	132.44	0.3235	202	1062.8	118.7	13385	-4.52	280.58	530.66	2.8626	254
Sanliurfa	Eyyubiye	10/10/2013	28	215.4	18.78	2582	1.53	47.22	77.83	0.5549	14	156.0	10.75	2002	7.29	19.02	48.49	0.7135	29	443.3	40.11	6041	10.23	5.14	161.45	0.4723	220	1740.2	170.95	20271	-3.32	193.68	538.88	2.6781	38
Sanliurfa	Eyyubiye	11/7/2014	69	525.9	38.5	6665	1.59	108.48	202.55	0.3866	6	83.5	6.47	1154	12.08	7.22	26.35	0.3392	11	190.3	17.88	2679	11.56	2.1	63.46	0.2918	198	1219.1	96.53	14637	-3.48	358.5	422.62	2.0121	163
Diyarbakir	Sur	1/22/2014	30	301.7	21.56	3950	-0.48	35.92	102.85	0.5601	17	242.5	19.07	3366	8.98	15.04	79.54	0.6528	25	409.6	38.69	5908	8.73	14.7	132.81	0.2926	139	1256.2	108.63	16659	-5.83	162.48	424.45	2.7043	233
Diyarbakir	Bismil	11/16/2011	29	367.4	28.54	4884	9.38	28.48	124.72	0.6071	17	277.0	20.58	3896	12.6	10.6	87.29	0.6681	24	491.1	58.76	7129	12.76	0.78	176.32	0.3036	212	1355.9	157.03	18384	-5.04	343.9	613.6	3.4567	248
Diyarbakir	Bismil	11/26/2013	42	392.1	29.77	5044	-0.91	36.5	137.21	0.6763	17	243.9	19.76	3382	8.31	14.3	82.37	0.7385	26	430.5	41.83	6206	8.82	12.56	144.32	0.6225	197	1327.4	123.44	17456	-10.14	190.5	479.58	3.5033	232
Diyarbakir	Bismil	12/8/2012	30	320.9	22.56	4137	6.26	34.94	106.7	0.612	22	306.7	21.95	4248	9.37	51.26	90.86	0.7194	16	274.3	26.09	3944	12.02	6.88	88.23	0.4207	179	1210.2	104.5	15691	-6	386.41	445.11	3.4079	317
Sanliurfa	Hilvan	11/27/2011	37	344.7	30.17	4523	7.53	19.76	128.47	0.484	13	196.1	13.03	2709	12.75	10.84	59.52	0.5138	16	257.9	21.22	3667	12.06	0.56	92.52	0.3053	185	1029.0	110.73	13434	-3.51	242.06	494.4	2.3835	247
Sanliurfa	Hilvan	12/9/2014	32	239.2	14.57	3048	4.72	70.92	90	0.4314	18	233.7	19.13	3197	4.51	6.42	84.22	0.4649	24	441.6	41.92	6304	11.37	4.88	149.72	0.1809	178	1242.2	104.05	15987	-3.58	315.28	458.78	2.1121	189
		Average:	35.71	302.6	23.93	3809	2.15	39.15	113.56	0.53	16.76	222.1	17.02	3005	8.41	15.29	74.12	0.65	21.27	341.8	28.83	4808	10.59	16.05	115.54	0.35	190.81	1272.8	110.85	15868	-3.49	274.37	468.71	2.74	200.93
		Std.Dev.:	12.76	92.0	6.86	1196	2.95	31.63	32.45	0.10	4.40	61.9	5.52	877	2.91	12.90	20.47	0.13	5.98	105.8	10.88	1506	1.97	19.16	36.78	0.14	16.10	223.3	19.60	2615	1.75	99.49	62.77	0.45	88.71







Variation of the correlations between the agro-meteorological indices and the phenological stage durations.

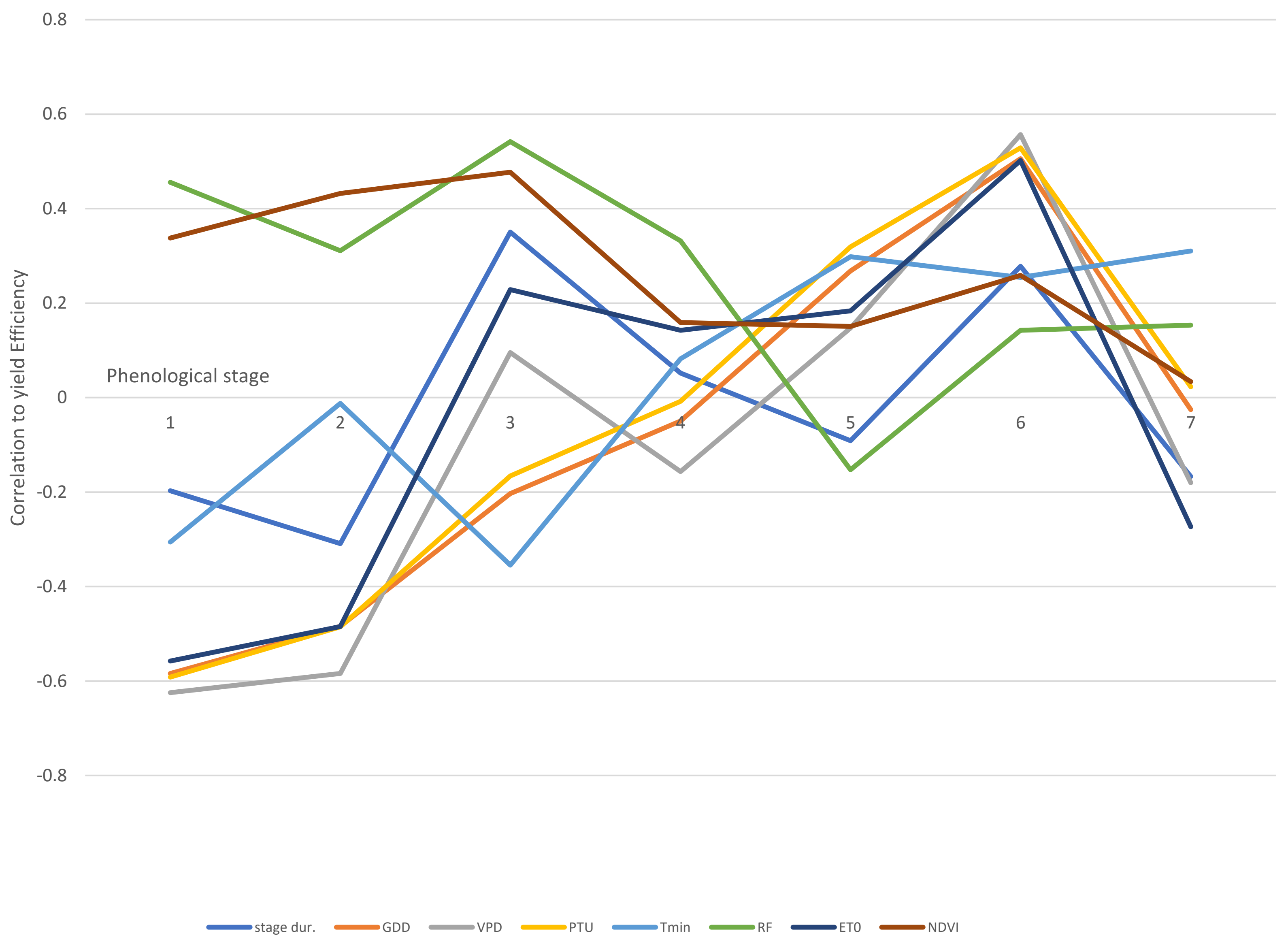
PS stage	Duration (d)	R^2
PS1	$0.8967 \times ET_0 – 0.9984 \times T_{min} + 7.0258$	0.818
PS2	$2.2669 \times VPD – 2.0421 \times T_{min} + 7.3934$	0.840
PS3	$1.4718 \times VPD – 1.5048 \times T_{min} + 0.1308 \times Prec. + 0.6922$	0.935
PS4	$0.0724 \times GDD + 0.1198 \times Prec. – 4.7053$	0.915
PS5	$0.1479 \times ET_0 + 0.0209 \times GDD + 1.2620$	0.967
PS6	$0.0035 \times PTU + 0.9313$	0.944
PS7	$0.0221 \times GDD + 0.0699 \times ET_0 + 0.5162$	0.979

How can we choose proper parameters and features in real-time Machine Learning ?

How can we avoid overfitting or underfitting problems?

Phenological stage segmented parameters' correlation to wheat yield efficiency

	Stage1	Stage2	Stage3	Stage4	Stage5	Stage6	Stage7
St.D.	-0.1970	-0.3093	0.3505	0.0517	-0.0913	0.2778	-0.1670
GDD	-0.5842	-0.4844	-0.2035	-0.0498	0.2678	0.5059	-0.0253
VPD	-0.6244	-0.5843	0.0952	-0.1566	0.1474	0.5566	-0.1802
PTU	-0.5919	-0.4851	-0.1661	-0.0081	0.3192	0.5288	0.0230
Tmin	-0.3057	-0.0125	-0.3547	0.0821	0.2985	0.2543	0.3102
RF	0.4559	0.3109	0.5418	0.3317	-0.1529	0.1423	0.1534
ET0	-0.5575	-0.4849	0.2285	0.1425	0.1834	0.5019	-0.2733
NDVI	0.3377	0.4322	0.4771	0.1588	0.1506	0.2588	0.0339


0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Correlation to yield Efficiency
Phenological stage
1
2
3
4
5
6
7
stage dur.
GDD
VPD
PTU
Tmin
RF
ET0
NDVI

	VPD6	VPD12	ARF1234	PTU56	Tmin7	Yield Eff. (kg/da)
	6.07	51.01	157.74	3621.39	10.03	38
	7.94	20.54	116.64	2690.08	2.51	171
	13.03	9.98	81.48	5798.1	9.59	144
	20.32	16.44	144.06	5929.16	9.13	271
	29.73	12.11	252.22	8066.38	11.39	284
	22.66	15.37	293.65	9328.96	13.42	256
	13.29	27.97	84.4	8049.57	12.61	136
	13.7	27.41	411.56	9282.93	13.77	303
	15.7	18.11	396.7	6723.64	12.62	270
	14.18	10.26	389.95	7325.63	13.17	349
	12.69	17.77	337.21	6396.51	11.7	226
	22.76	8.97	172.05	7732.59	10.17	292
	13.86	11.5	336.72	5759.22	12.1	268
	24.28	6.84	285.96	7509.15	11.66	270
	16.42	9.1	373.8	6729.33	12.69	310
	14.83	9.2	112.15	5331.35	11.13	203
	11.31	27.83	106.98	5140.28	10.82	38
	26.43	9.45	81.34	9651.8	12.26	230
	14.64	13.43	187.08	5723.36	10.49	160
	17.47	39.61	88.26	7665	11.57	89
	21.38	17.5	249.22	5737.32	12.06	223
	11.27	6.54	188.64	5545.36	11.64	160
	20.83	12.64	188.18	5772.36	11.72	254
	10.75	77.58	122.3	4583.42	10.23	38
	6.47	13.35	240.7	7819.03	11.56	163
	19.07	15.12	96.82	7315.67	8.73	233
	20.58	23.03	304.04	8779.33	12.76	248
	19.76	19.52	127.14	8426.76	8.82	232
	21.95	12.31	293.33	8384.5	12.02	317
	13.03	15.7	210.9	7231.78	12.06	247
	19.13	6.52	233.06	6245.11	11.37	189
Average:	16.630	18.797	214.977	6783.712	11.155	213.290
St.Dev.:	5.638	14.405	103.087	1625.187	2.028	81.659
R:	0.557	-0.652	0.646	0.521	0.310	1.000

$$YE = 119.52 + 4.418 \cdot VPD6 - 1.908 \cdot VPD12 + 0.501 \cdot ARF1234 + 0.0123 \cdot PTU56 - 12.116 \cdot Tmin$$

	VPD6	VPD12	ARF 1234567	Actual Yield Eff.	Predicted Yield Eff.	Error
	6.07	51.01	180.26	38	40.59	-2.59
	7.94	20.54	374.28	171	191.99	-20.99
	13.03	9.98	180.3	144	156.25	-12.25
	20.32	16.44	202.06	271	201.13	69.87
	29.73	12.11	329.08	284	325.21	-41.21
	22.66	15.37	335.54	256	277.41	-21.41
	13.29	27.97	190.5	136	131.18	4.82
	13.7	27.41	495.12	303	270.60	32.40
	15.7	18.11	444.68	270	277.01	-7.01
	14.18	10.26	496.85	349	304.24	44.76
	12.69	17.77	359.69	226	220.54	5.46
	22.76	8.97	270.85	292	260.33	31.67
	13.86	11.5	436.44	268	273.11	-5.11
	24.28	6.84	351.35	270	309.61	-39.61
	16.42	9.1	402.06	310	278.25	31.75
	14.83	9.2	196.01	203	176.07	26.93
	11.31	27.83	139.62	38	96.12	-58.12
	26.43	9.45	160.76	230	233.77	-3.77
	14.64	13.43	278.72	160	204.39	-44.39
	17.47	39.61	170.92	89	128.82	-39.82
	21.38	17.5	284.38	223	242.75	-19.75
	11.27	6.54	274.16	160	192.88	-32.88
	20.83	12.64	280.58	254	246.00	8.00
	10.75	77.58	193.68	38	30.17	7.83
	6.47	13.35	358.5	163	188.09	-25.09
	19.07	15.12	162.48	233	177.82	55.18
	20.58	23.03	343.9	248	254.58	-6.58
	19.76	19.52	190.5	232	187.06	44.94
	21.95	12.31	386.41	317	300.90	16.10
	13.03	15.7	242.06	247	173.84	73.16
	19.13	6.52	315.28	189	261.29	-72.29
Average:	16.630	18.797	291.194	213.290	213.290	0.000
St.Dev.:	5.638	14.405	101.956	81.659	73.281	36.029
R:	0.557	-0.652	0.648	1.000	0.897	

$$YE = 10.24 + 6.367 \cdot VPD6 - 1.739 \cdot VPD12 + 0.446 \cdot ARF1234567$$

Minimum (COV/R^2) → Maximum(Estimation Confidence Factor)

$$YE = 119.52 + 4.418 \cdot VPD6 - 1.908 \cdot VPD12 + 0.501 \cdot ARF1234 + +0.0123 \cdot PTU56 - 12.116 \cdot Tmin$$

R^2 = 0.83

$$YE = 10.24 + 6.367 \cdot VPD6 - 1.739 \cdot VPD12 + 0.446 \cdot ARF1234567$$

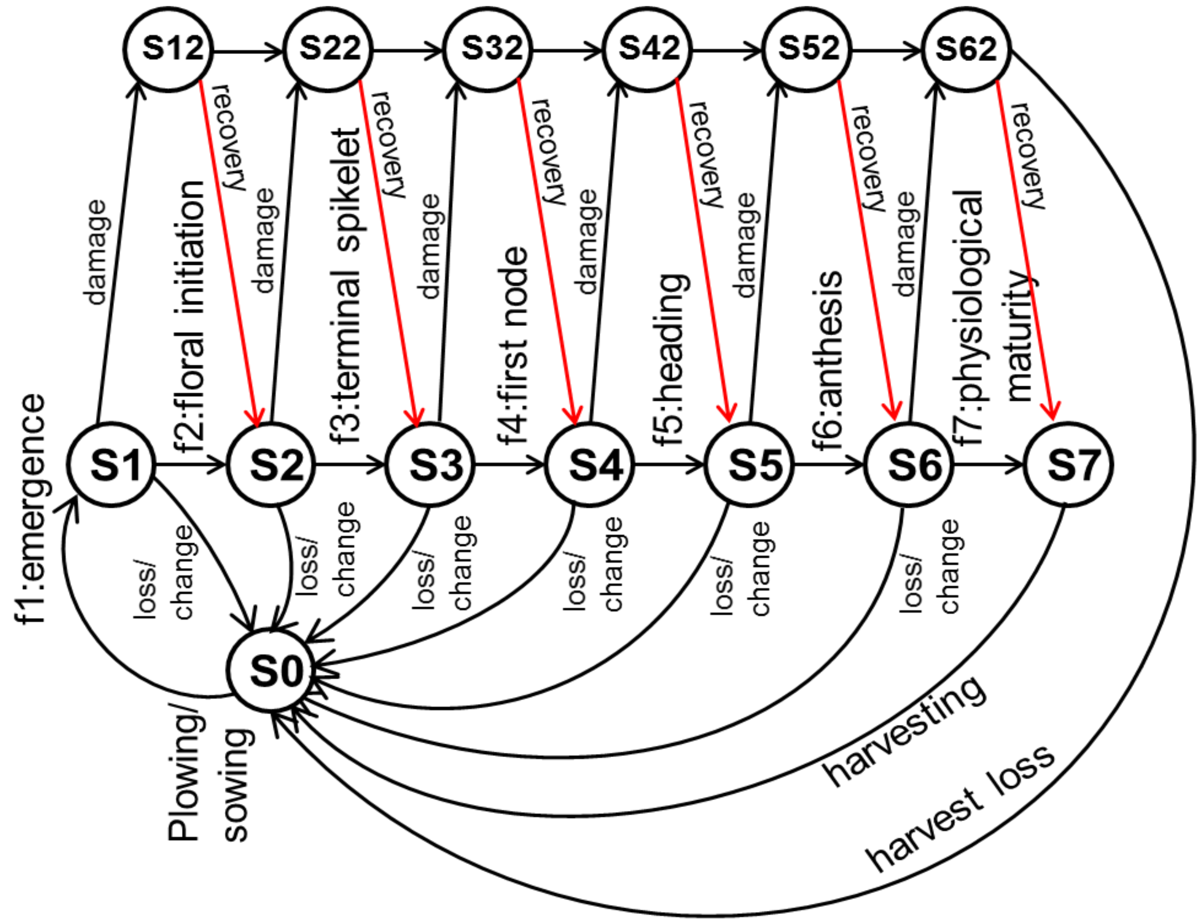
R^2 = 0.81

$$YE = -34.163 + 5.187 \cdot VPD6 - 2.088 \cdot VPD12 + 0.392 \cdot ARF1234567 + 31.58 \cdot NDVI1234567$$

R^2 = 0.83

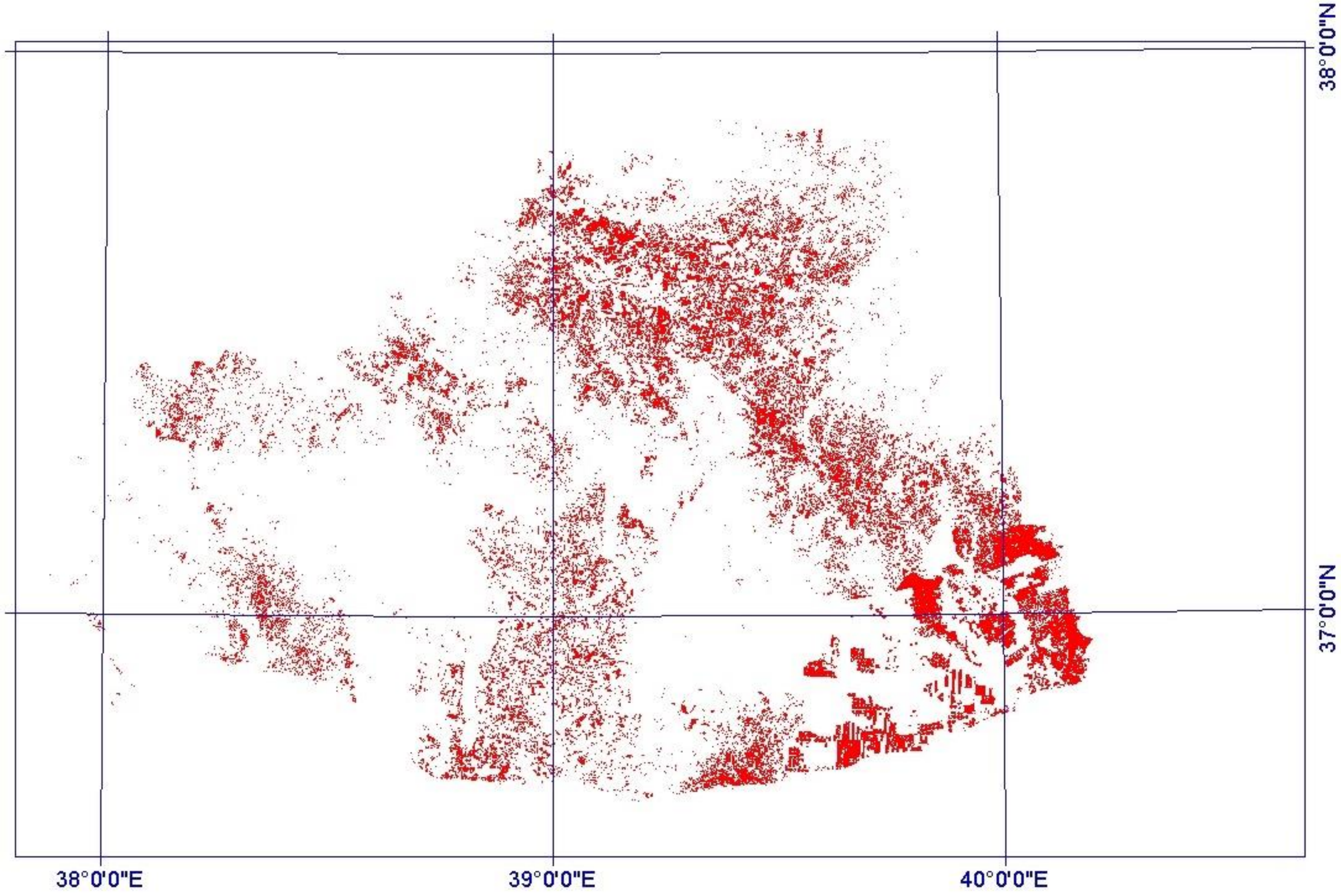
$$YE = -8.046 + 5.559 \cdot VPD6 - 1.896 \cdot VPD12 + 0.386 \cdot ARF1234567 + 147.76 \cdot NDVI3$$

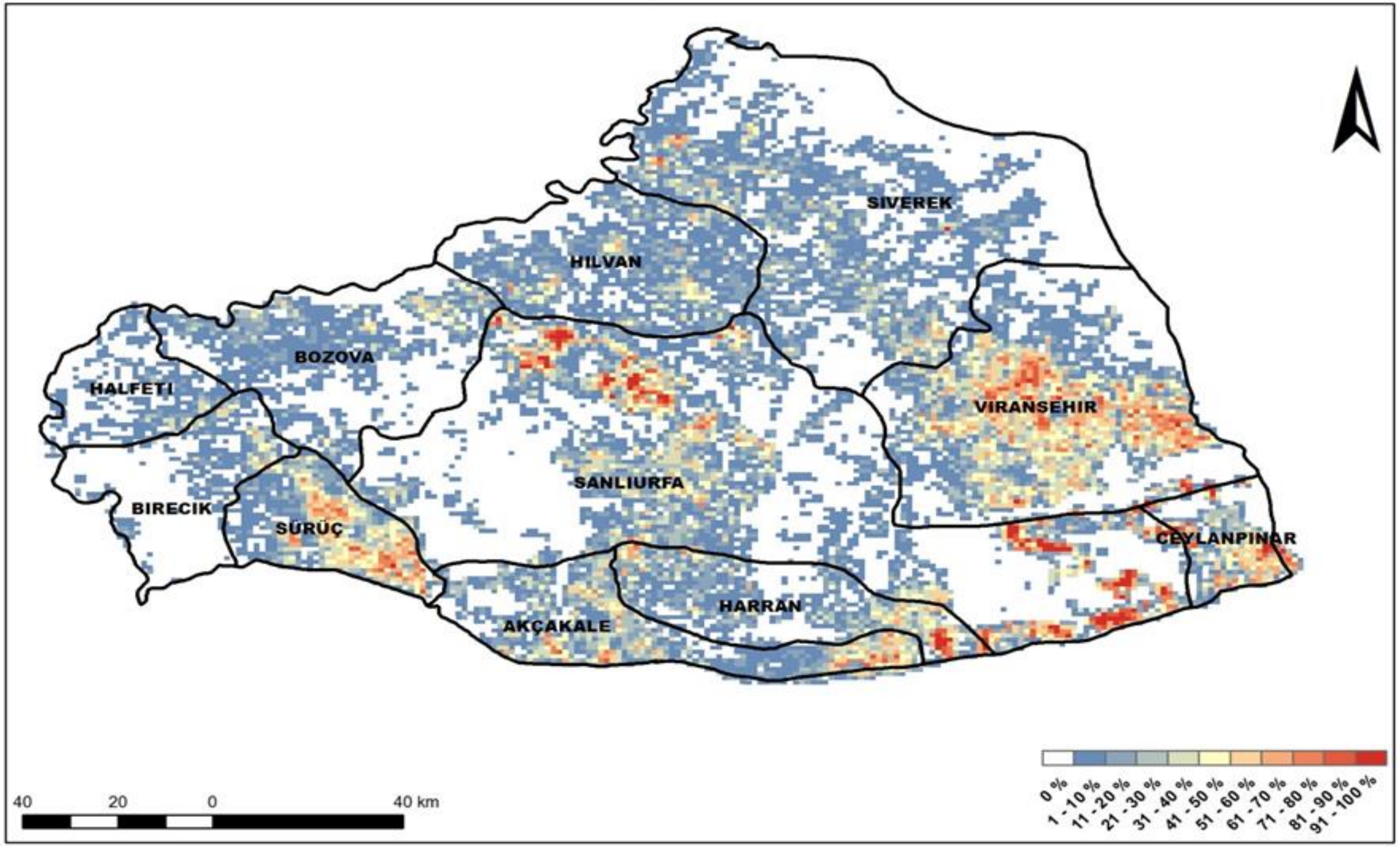
R^2 = 0.84



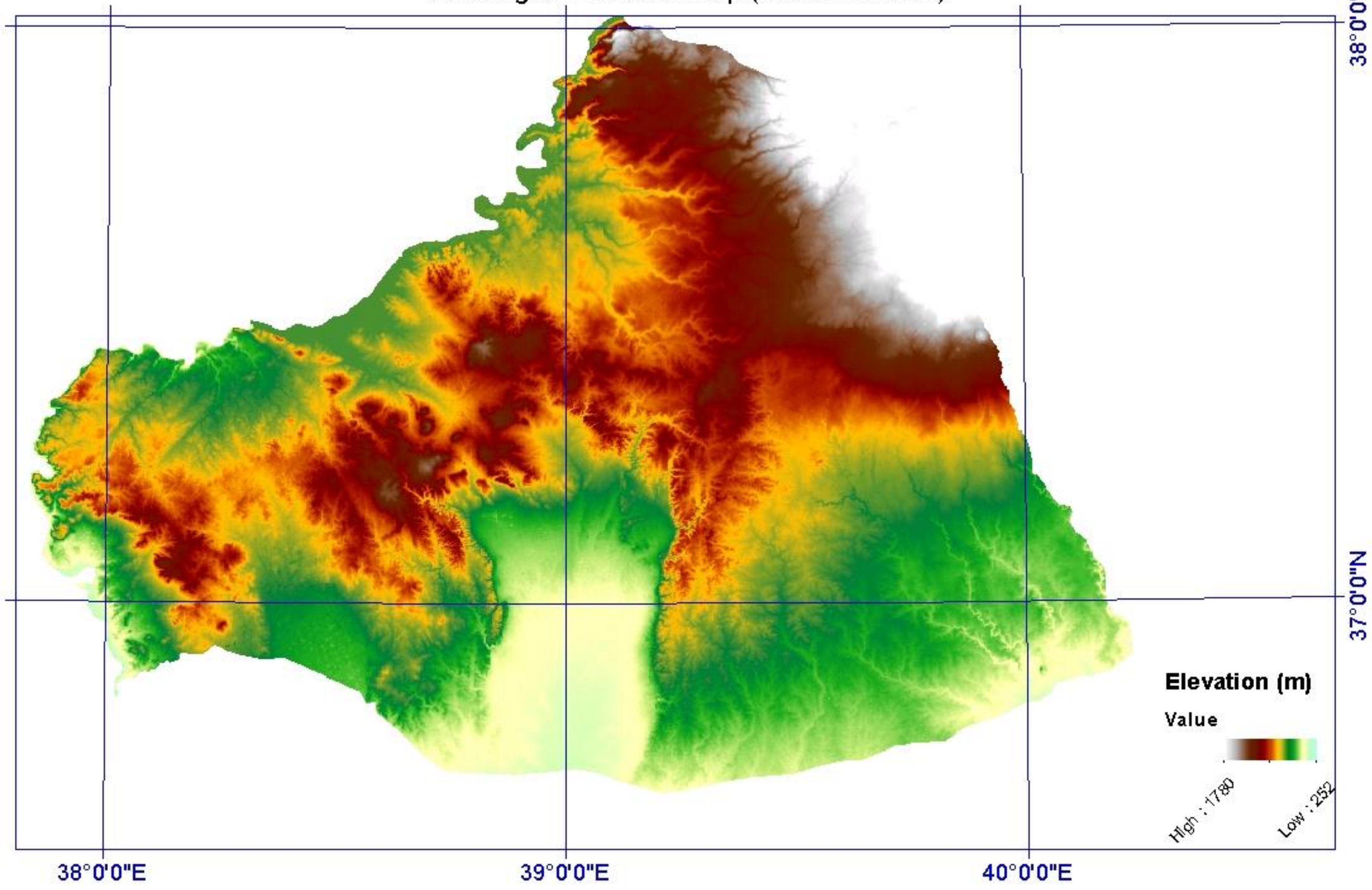
State machine for more complex roadmaps to possible permanent damage

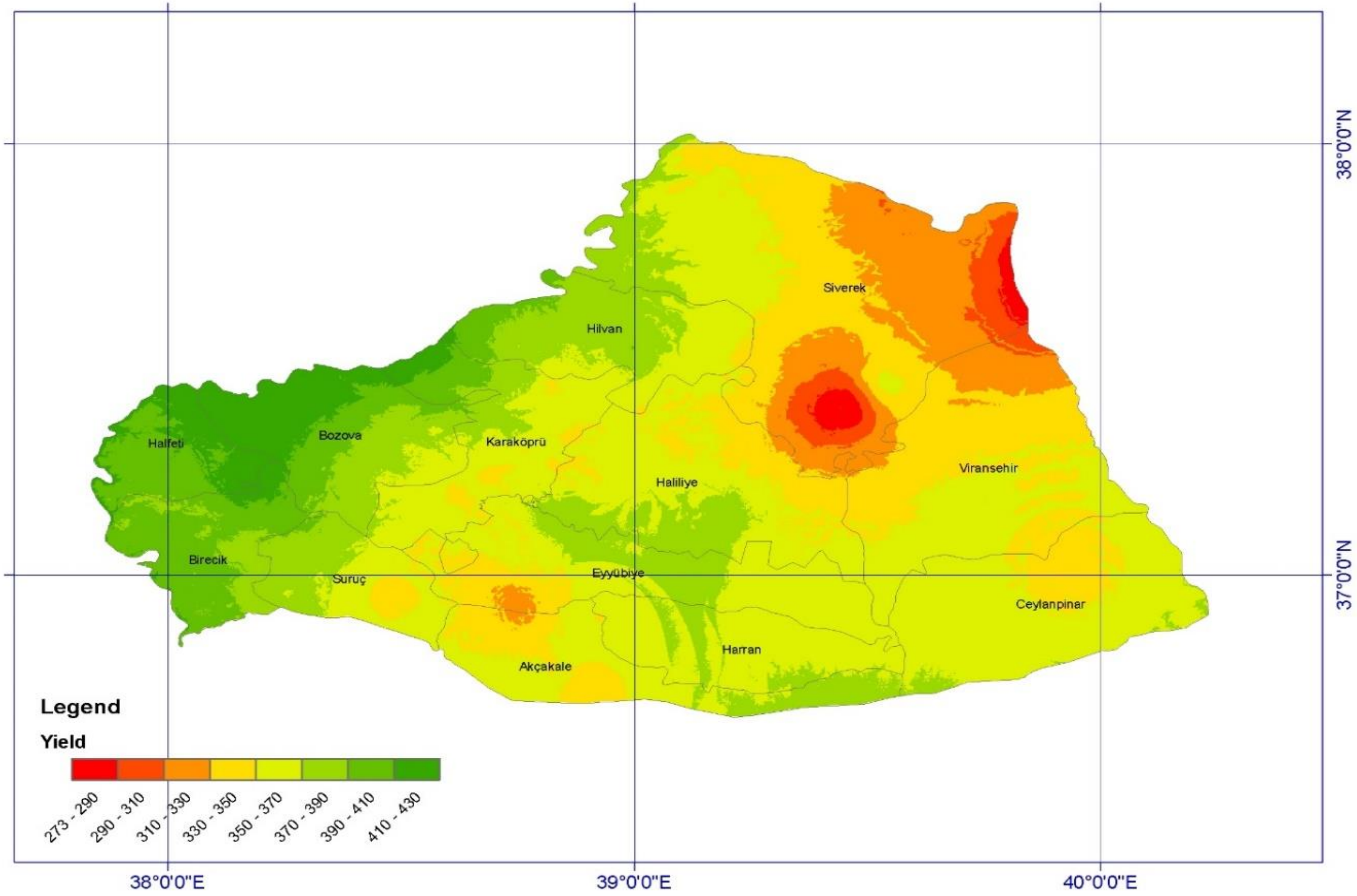
Winter wheat detected area in Şanlıurfa province (2015)

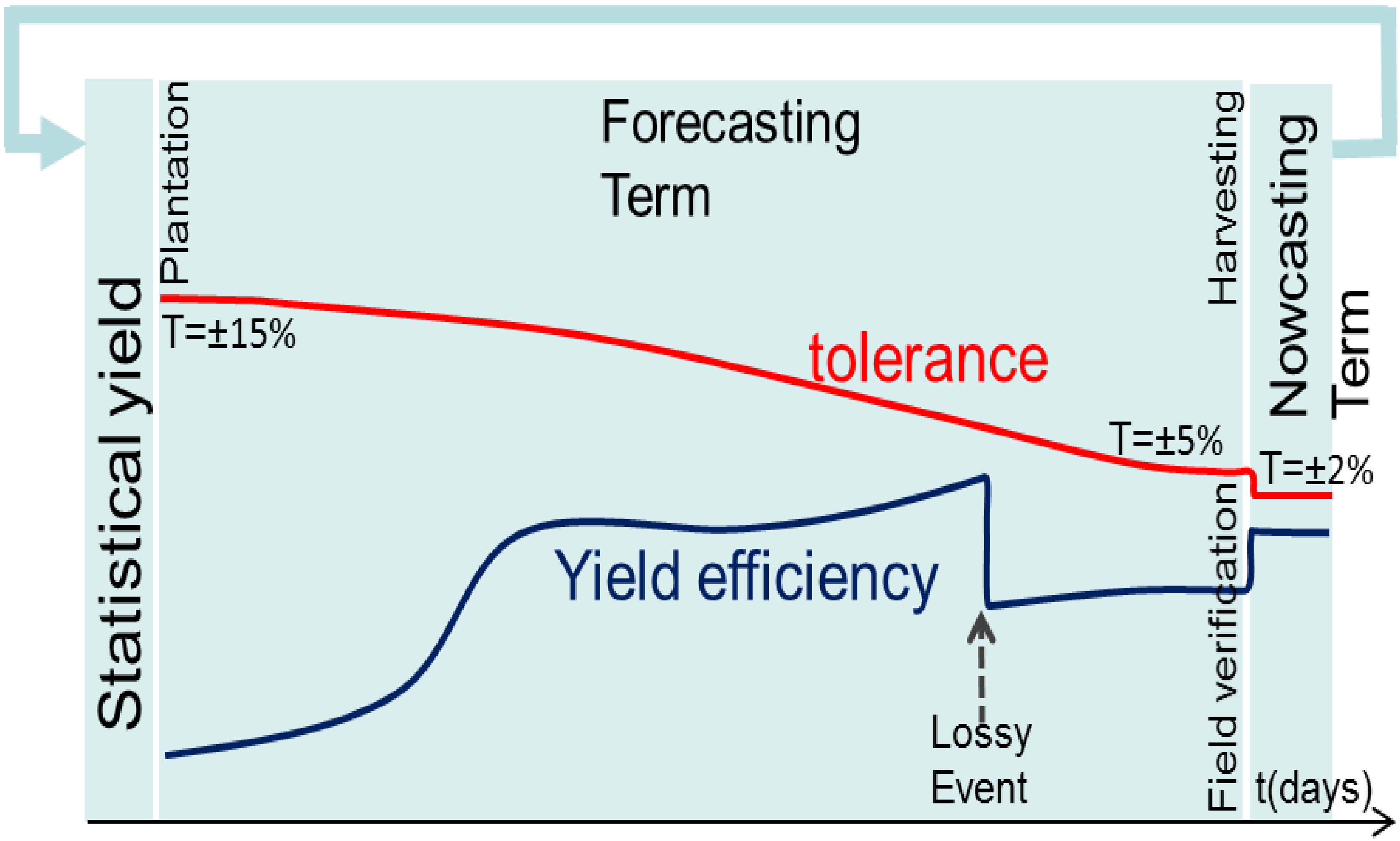



SIVEREK
HILVAN
BOZOVA
HALFETI
VIRANSEHIR
SANLIURFA
BIRECIK
SÜRÜÇ
CEYLANPINAR
HARRAN
AKÇAKALE
0 %
1 - 10 %
11 - 20 %
21 - 30 %
31 - 40 %
41 - 50 %
51 - 60 %
61 - 70 %
71 - 80 %
81 - 90 %
91 - 100 %
40
20
0
40 km

Urfa Digital Elevation Map (ASTER GDEM)



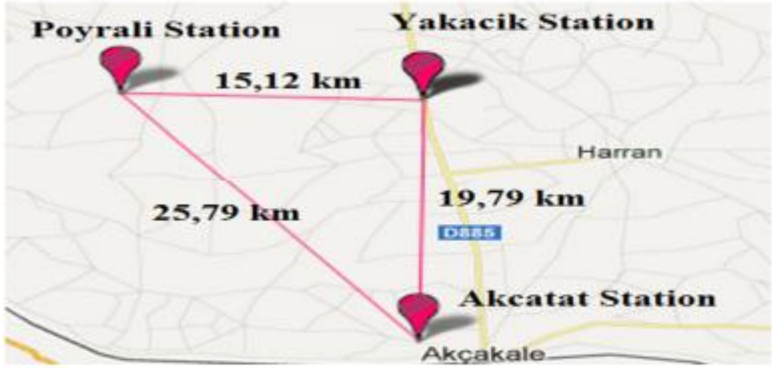

38°0'0"E
39°0'0"E
40°0'0"E
38°0'0"N
37°0'0"N
Siverek
Hilvan
Halfeti
Bozova
Karaköprü
Viransehir
Haliliye
Birecik
Suruç
Eyyübiye
Ceylanpinar
Harran
Akçakale
Legend
Yield
273 - 290
290 - 310
310 - 330
330 - 350
350 - 370
370 - 390
390 - 410
410 - 430

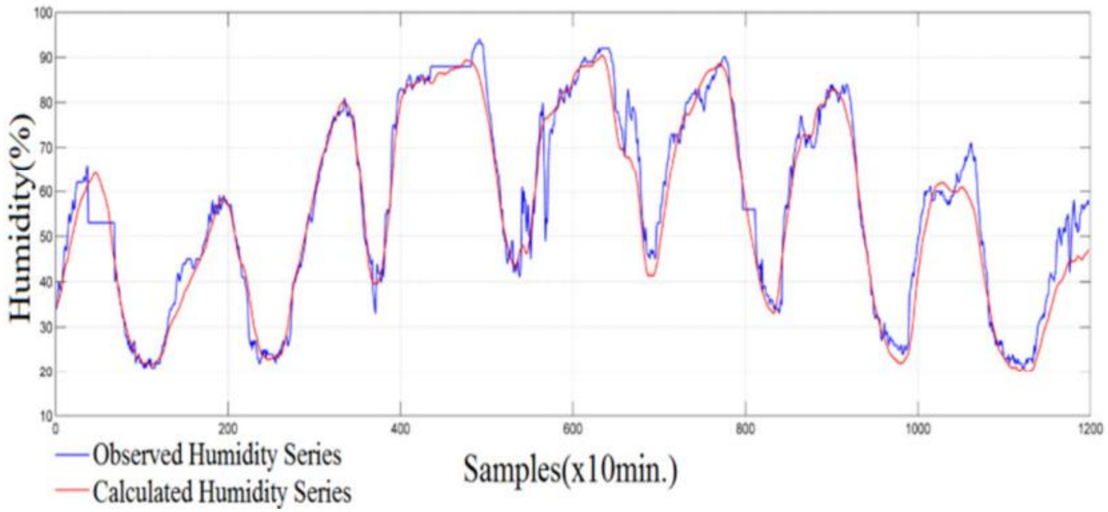


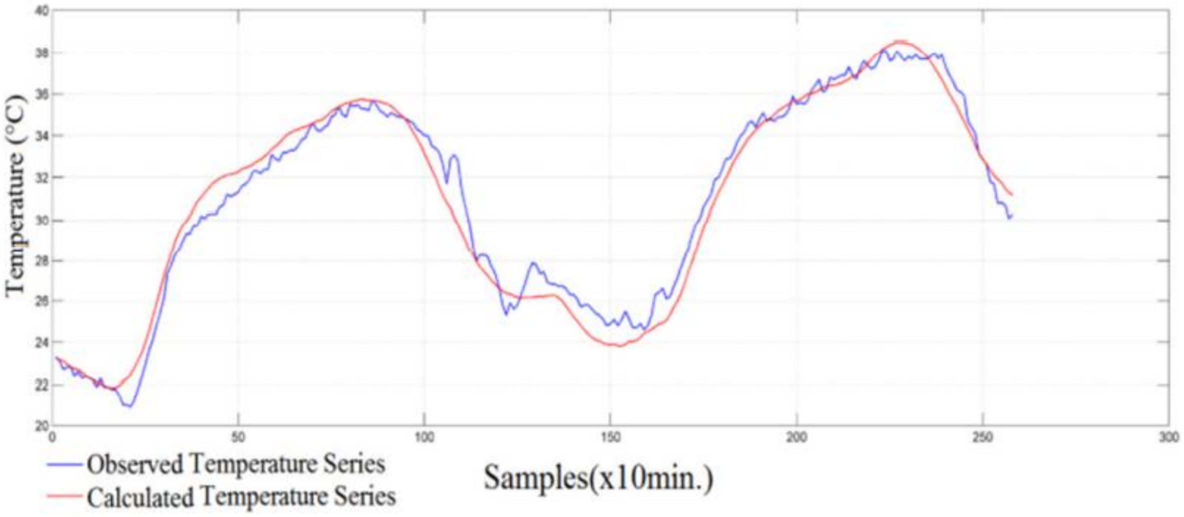
$$YE = \mu_{YE} \mp Zc \cdot \frac{\sigma_{YE}}{\sqrt{n}}$$

QoS Management in Twinning Process

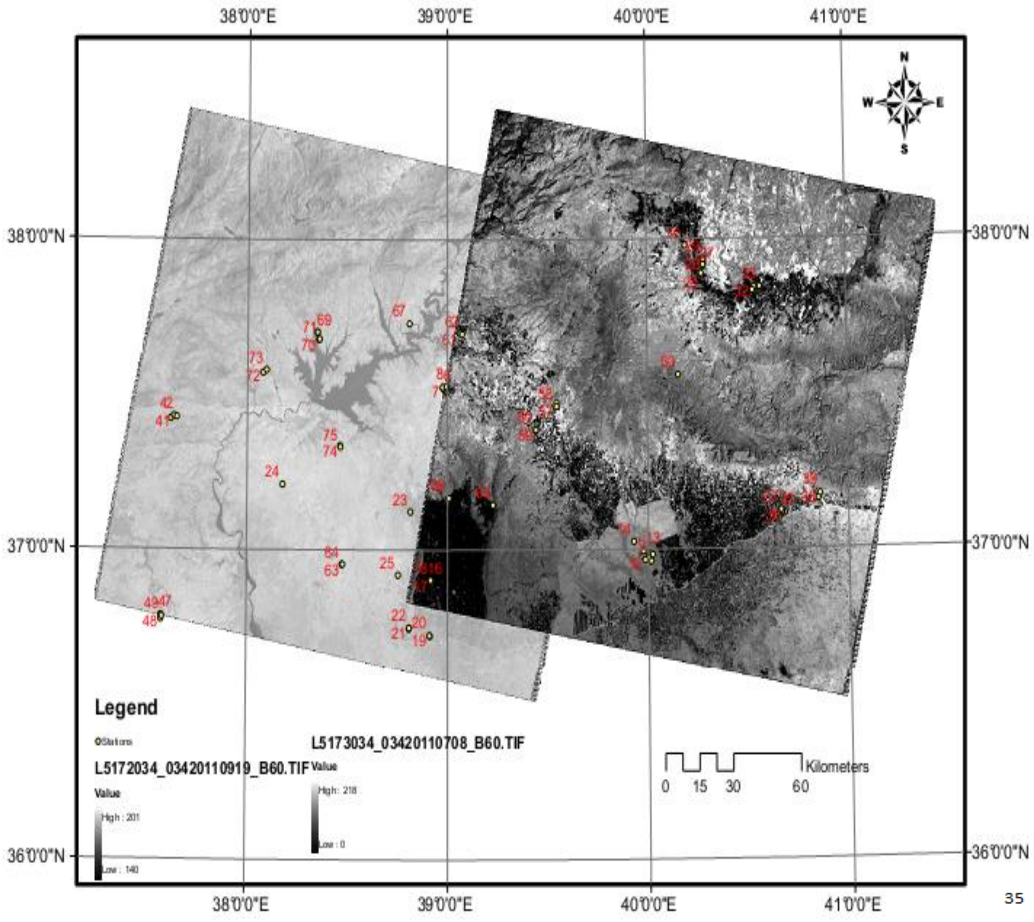
a) Real-time missing data reconstruction example:

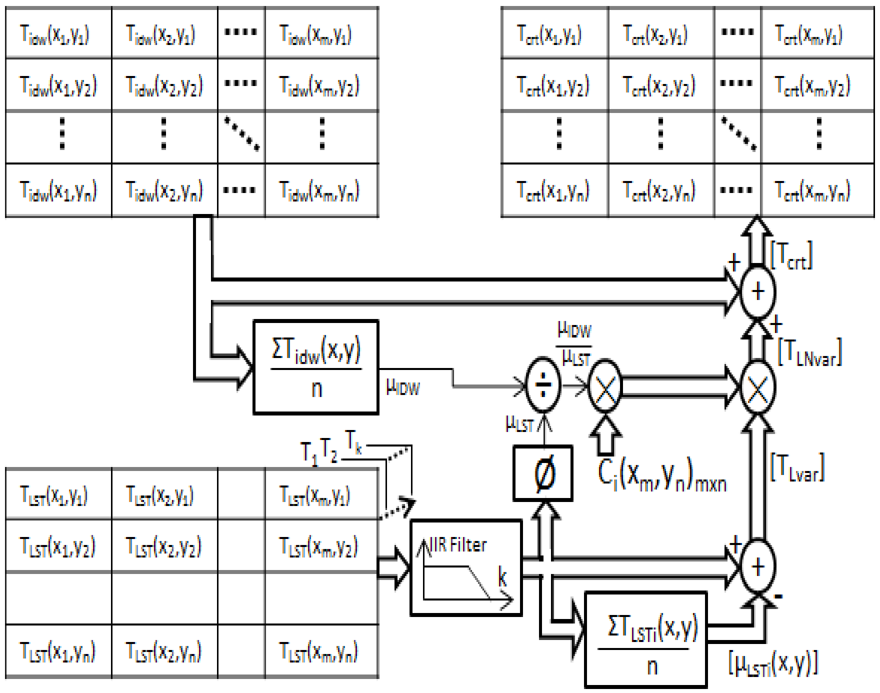






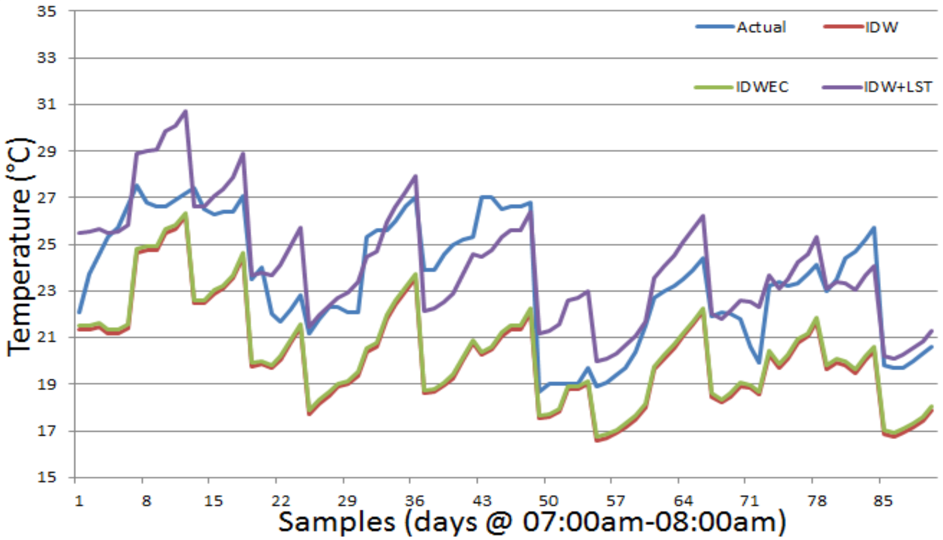
b) Accuracy
& Tolerance
Management



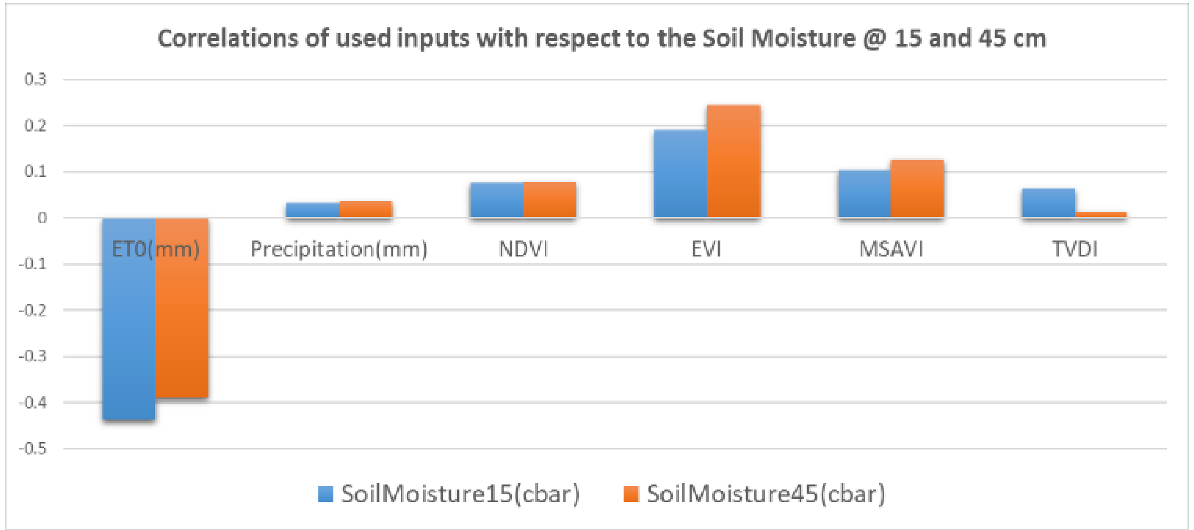


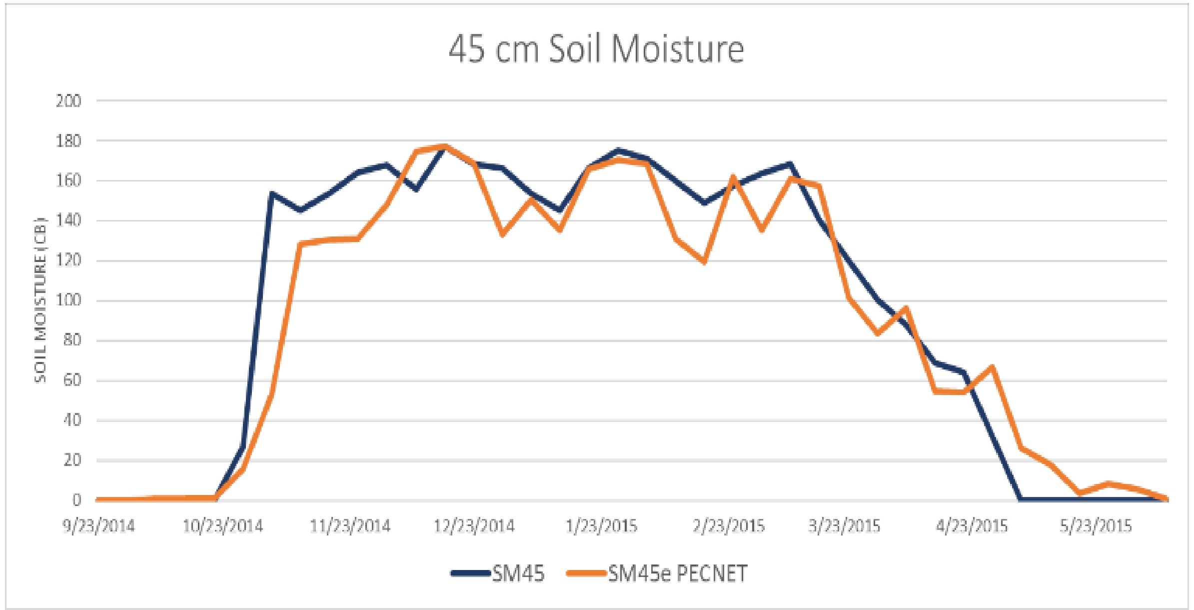
Adaptive model based quality improvement of spatio-temporal fusion data

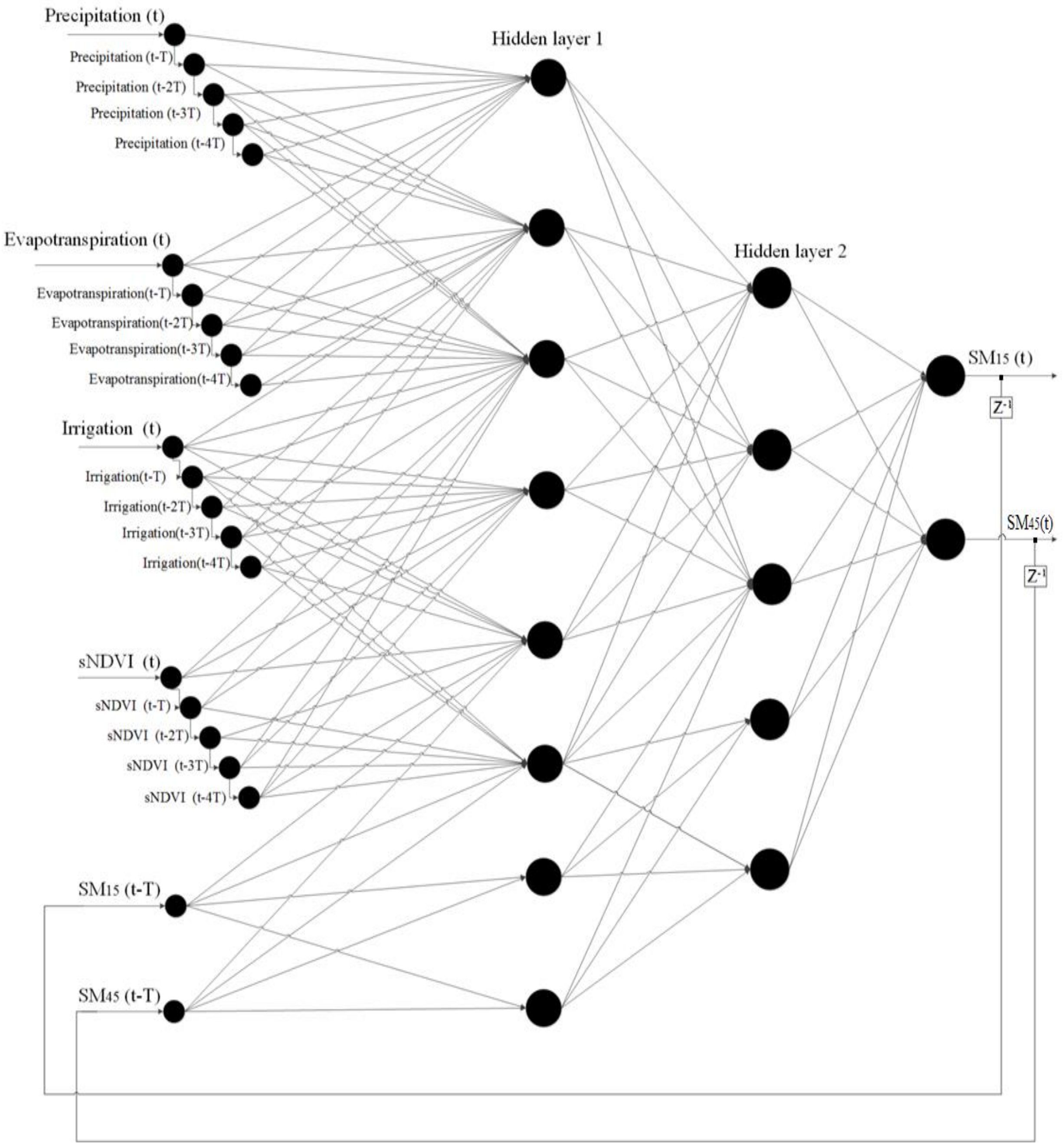
Example: 250m fused temperature
Data interpolation MSE is less than 1°C



Performance improvement with small data in ML? →PECNET





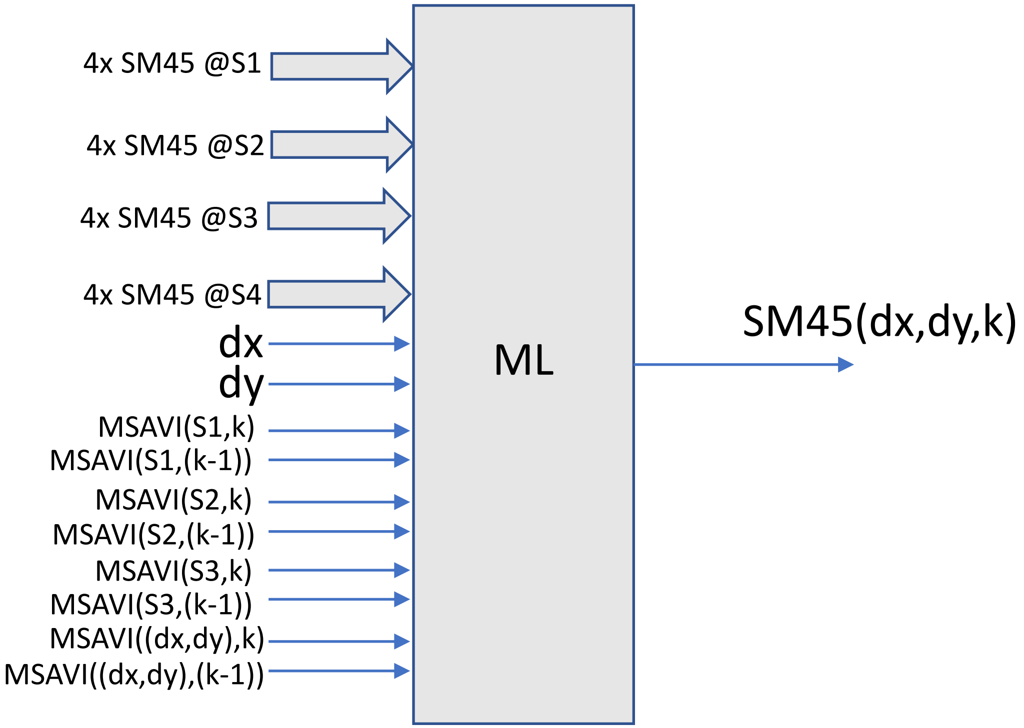


Problem in Spatio Temporal Data Fusion:

Over Fitting (How to choose the proper time window and the data type)

Over Fitting (How to process, ML type and Hyperparameter selection)

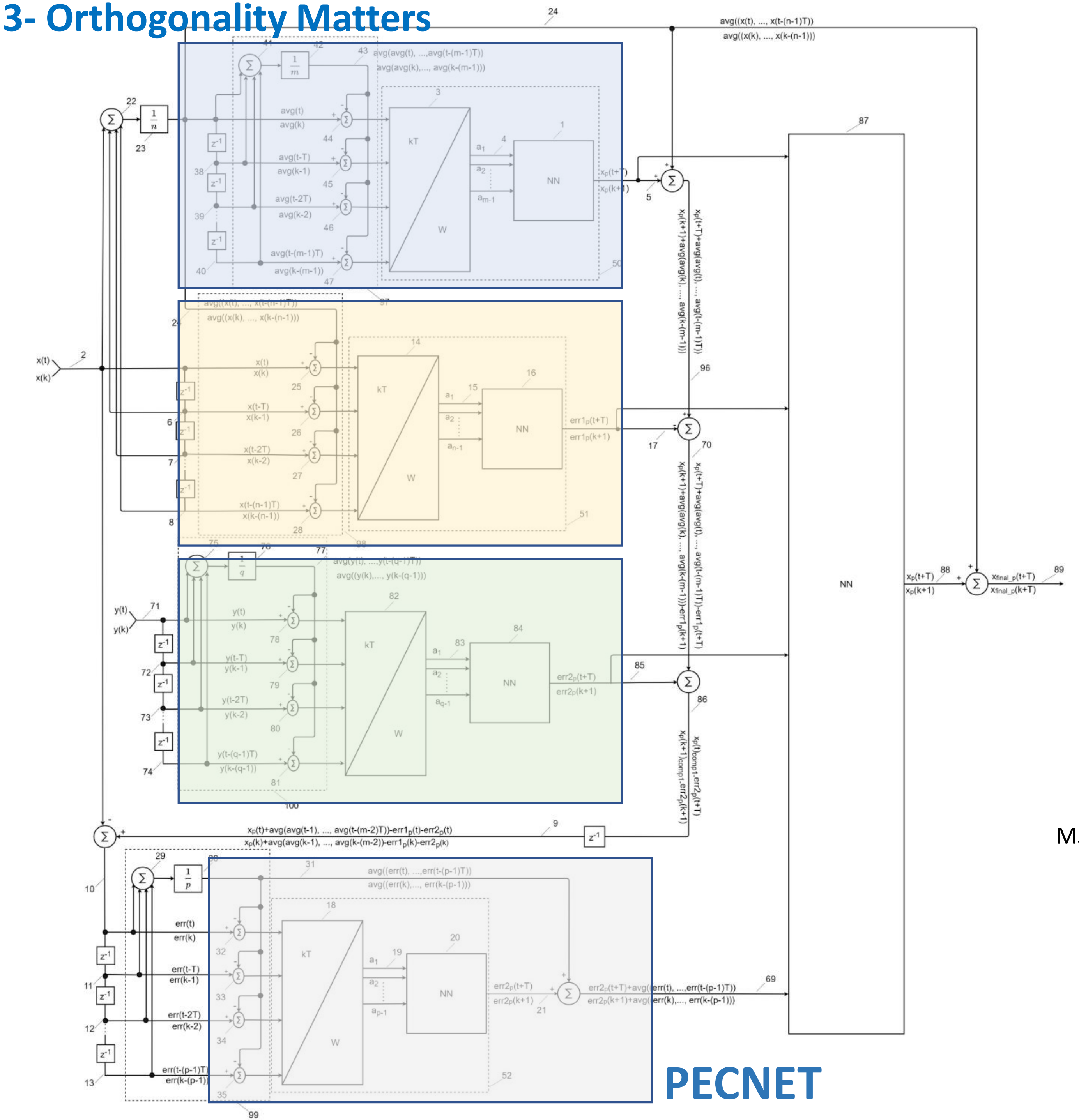
Over Fitting (How to struggle against non-linearity, uncertainity under and restricted labled data)



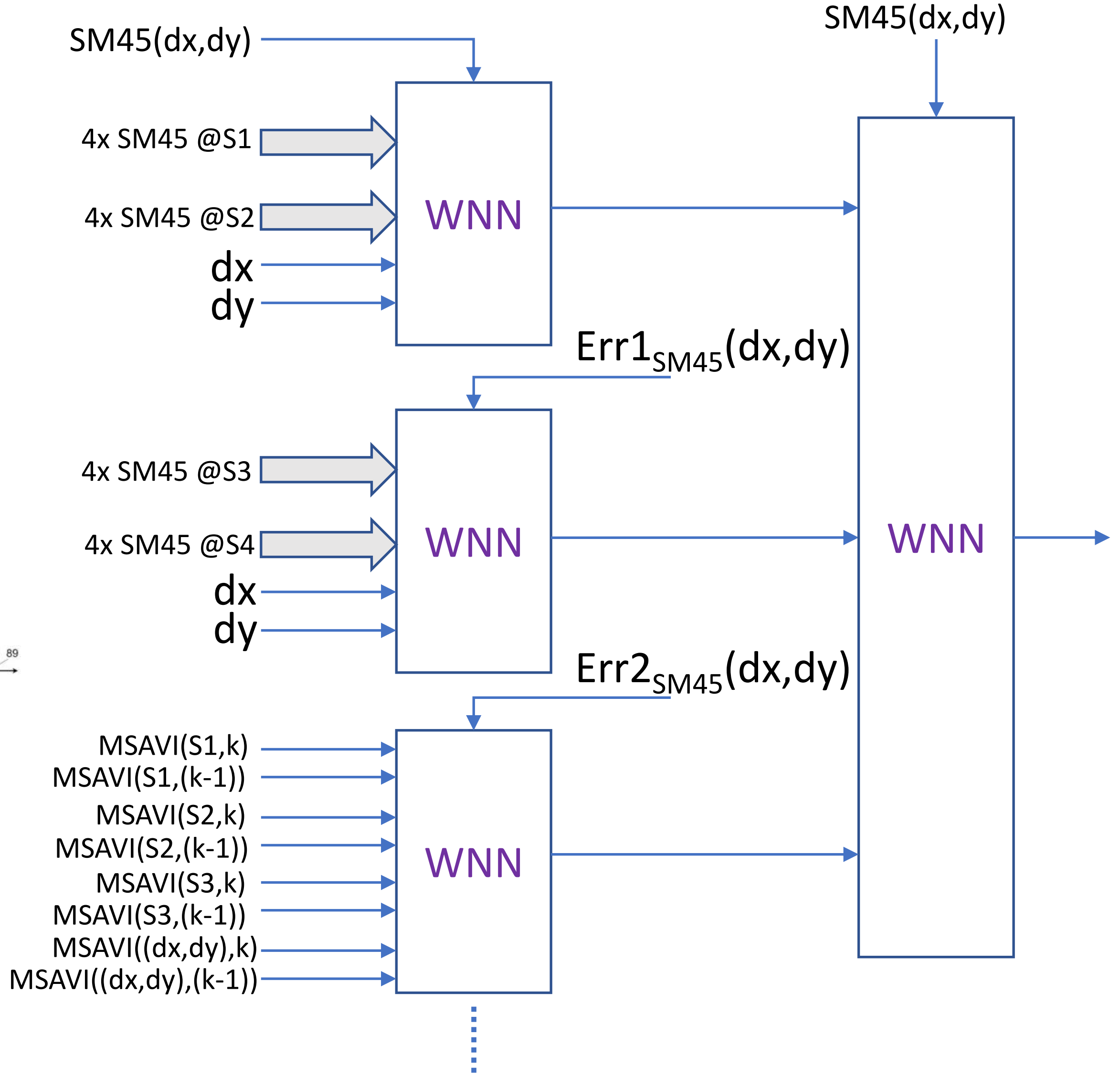
Accuracy of test ?

Tolerance ?

3- Orthogonality Matters



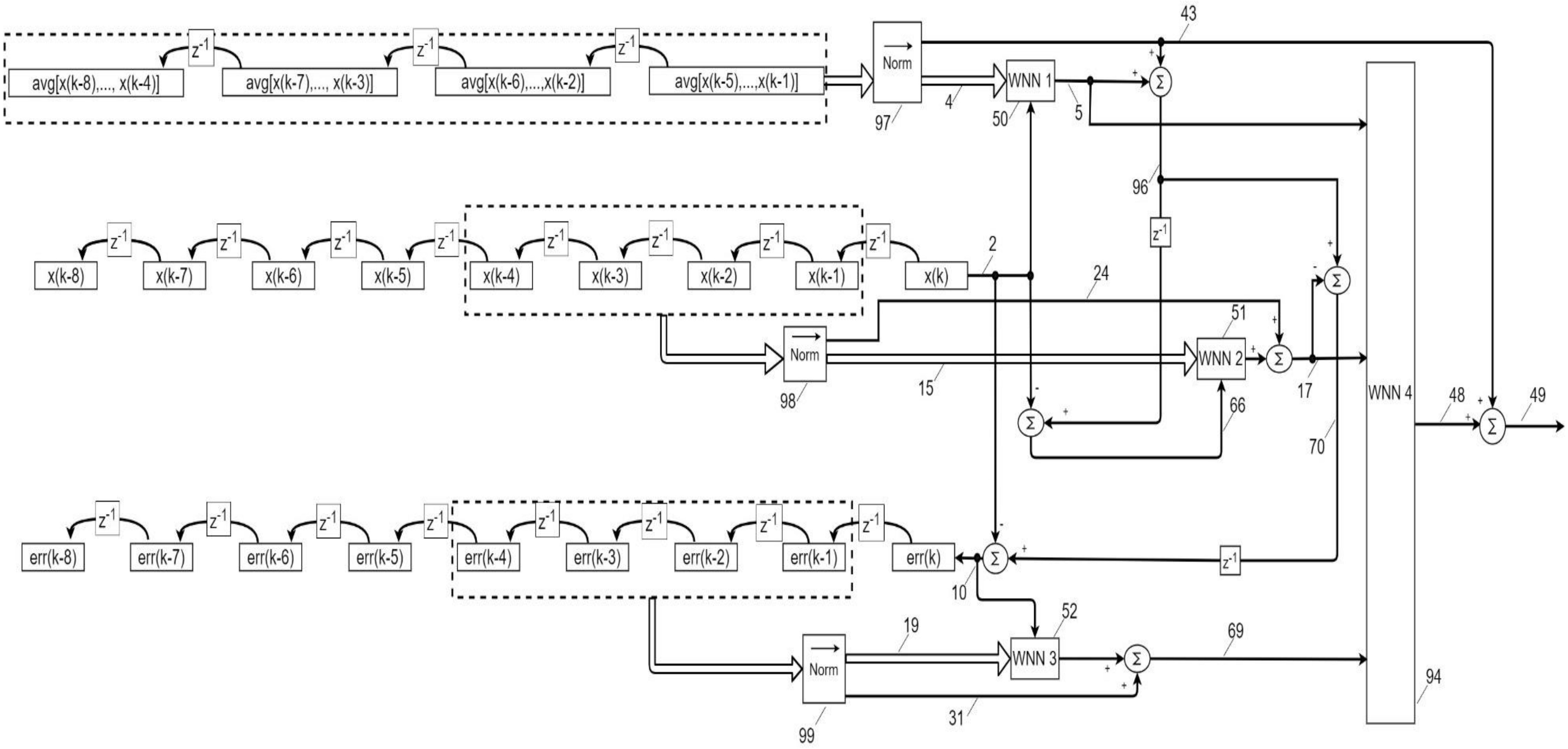
PECNET

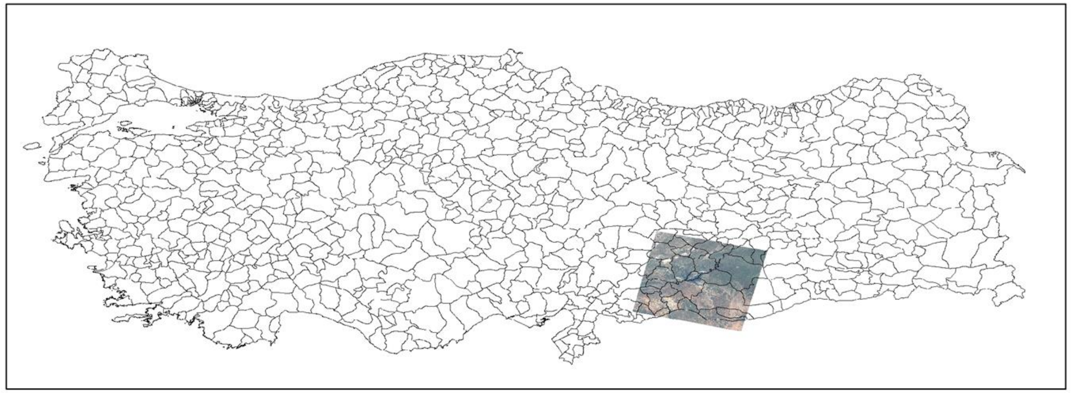


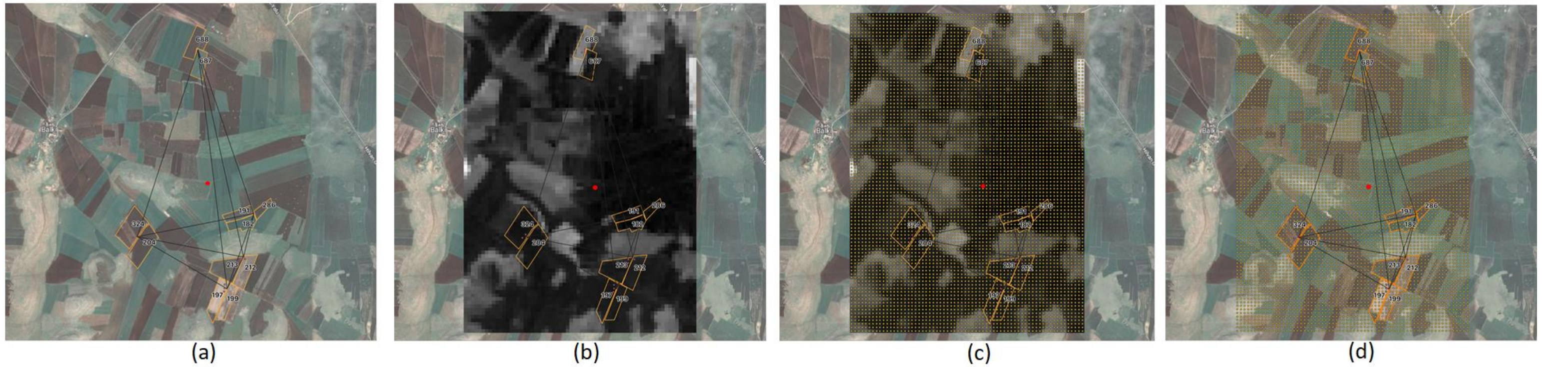
RMSE (cb): 0..200cb

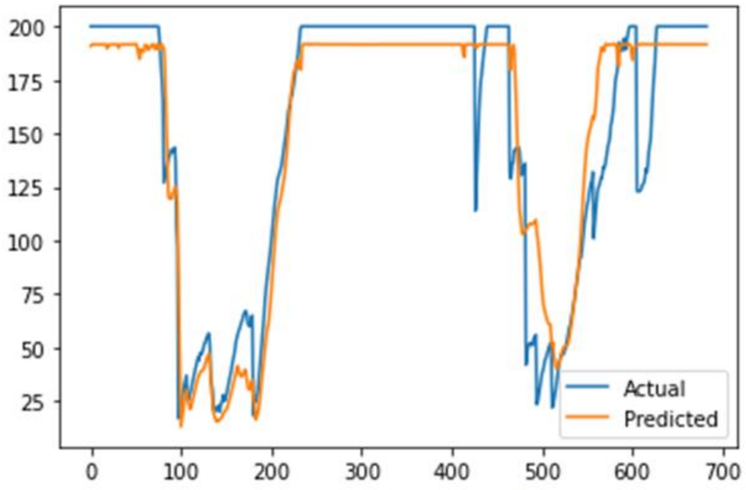
SM45	Regression	LSTM	CNN	ANN	PECNET
SM	39	22	23	26	22
SM, MSAVI	42	22	24	28	17
(RF-ET0), MSAVI	46	23	27	31	18

4- Continual Learning

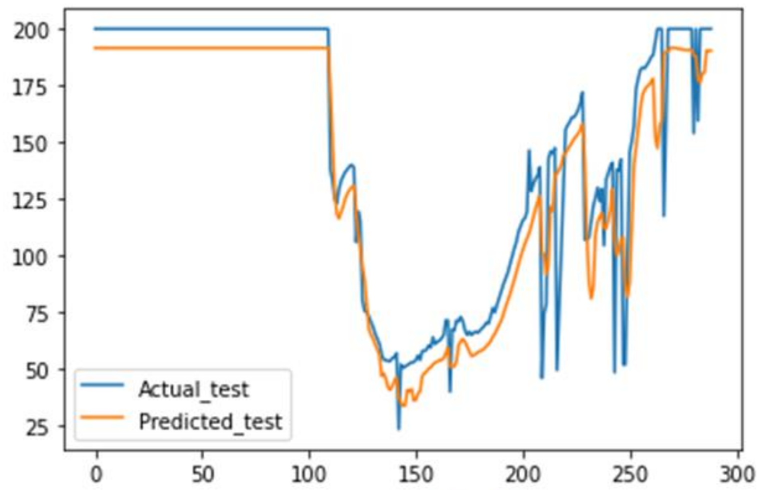




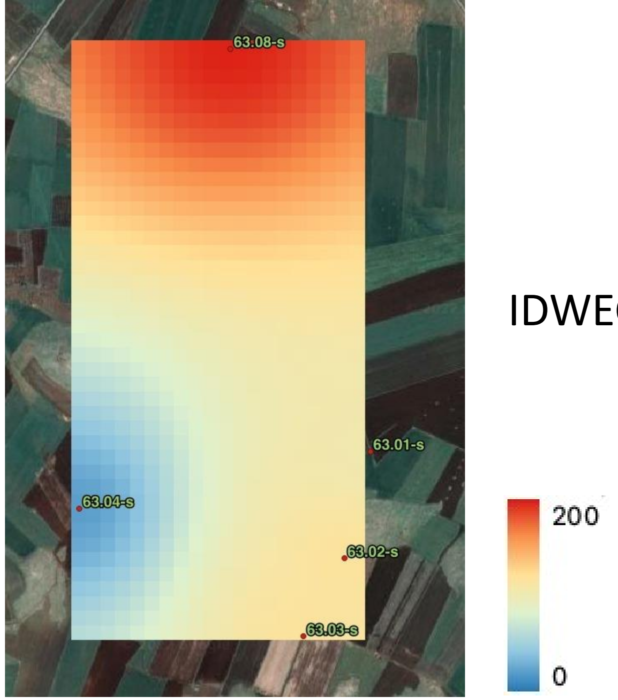




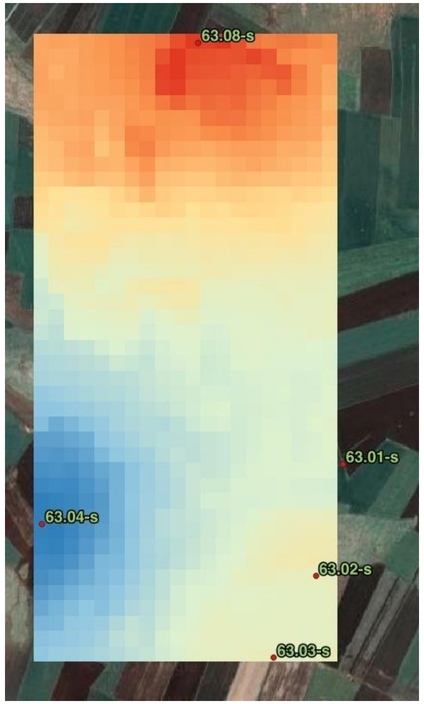
(a_training)



(a_test)

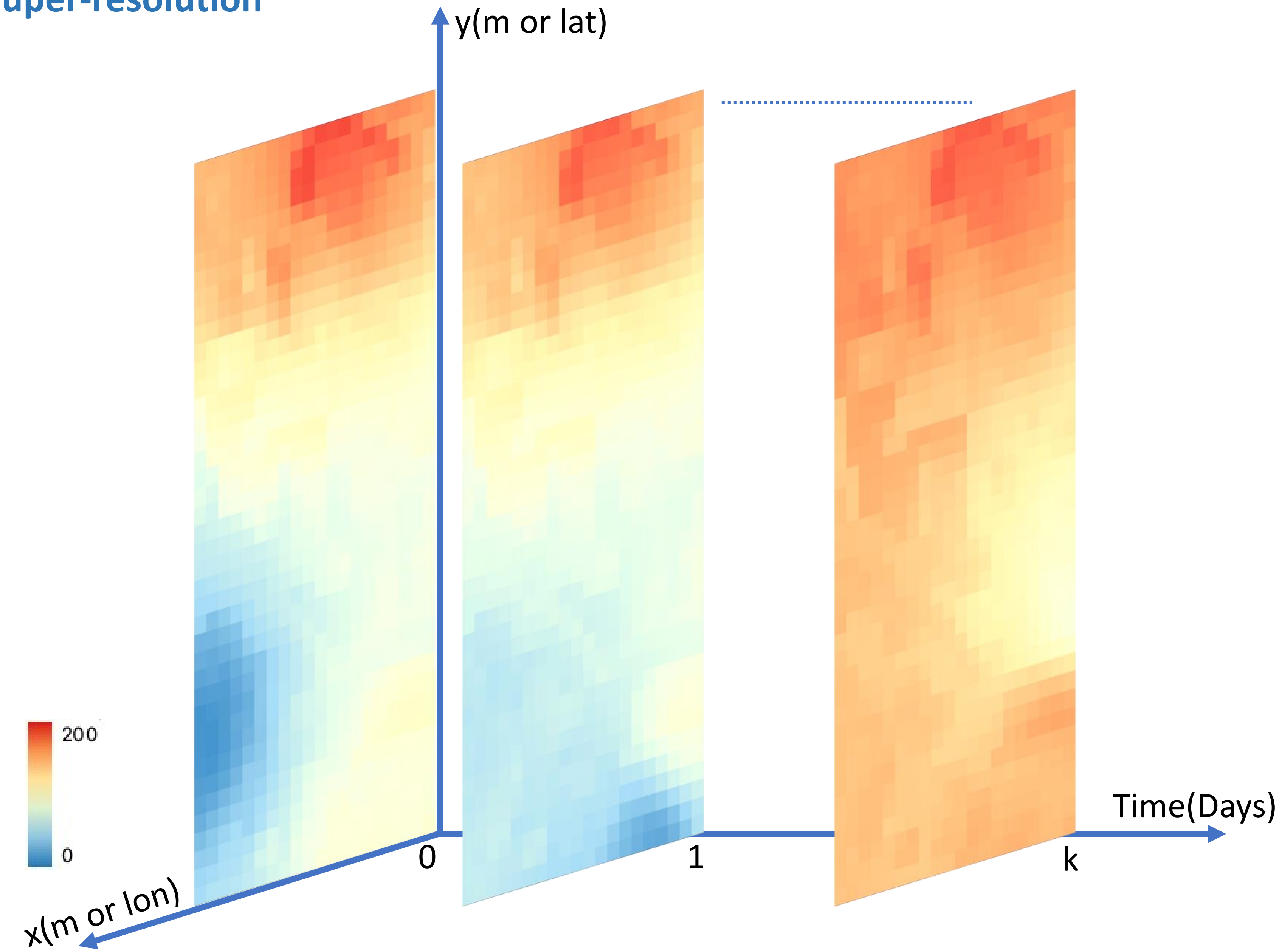


IDWEC

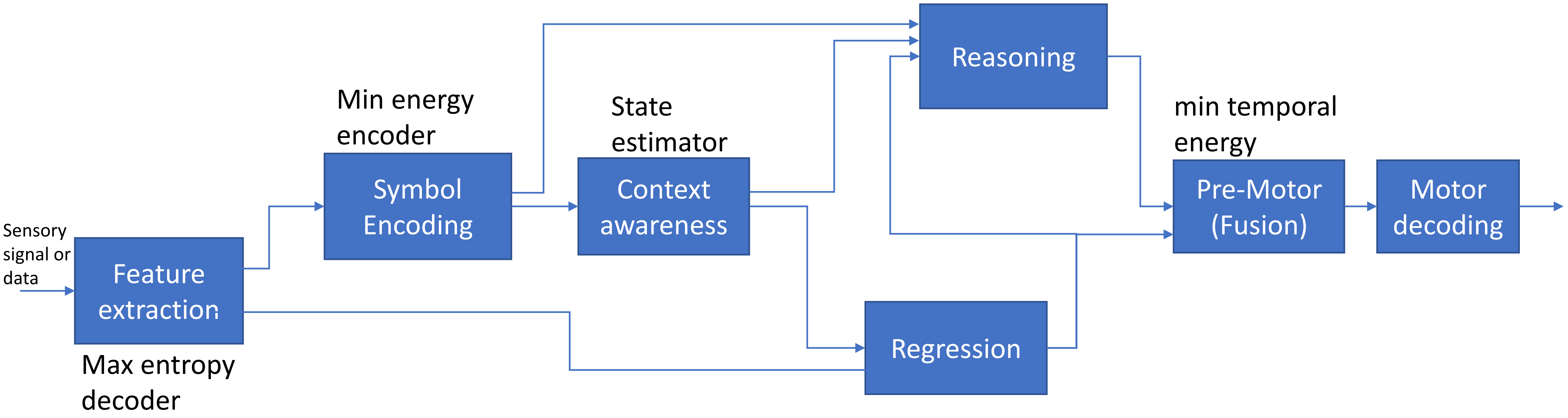


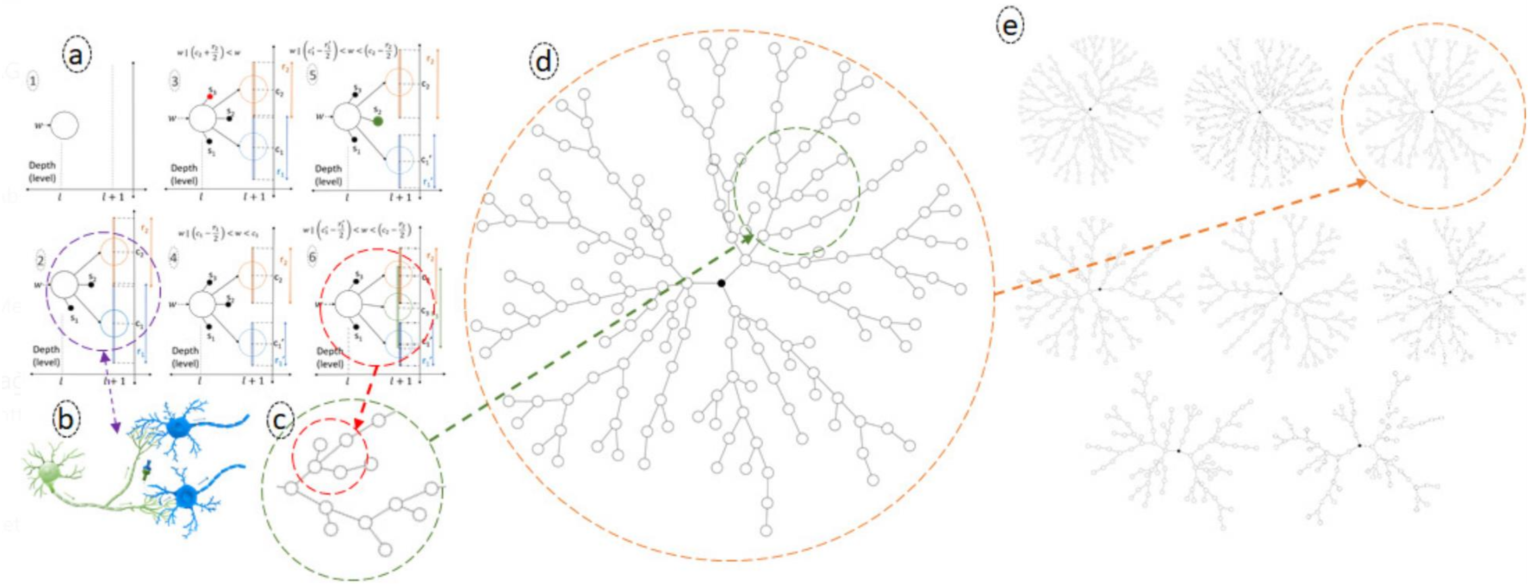
PECNET Twin

Spatio-temporal super-resolution fusion for casting



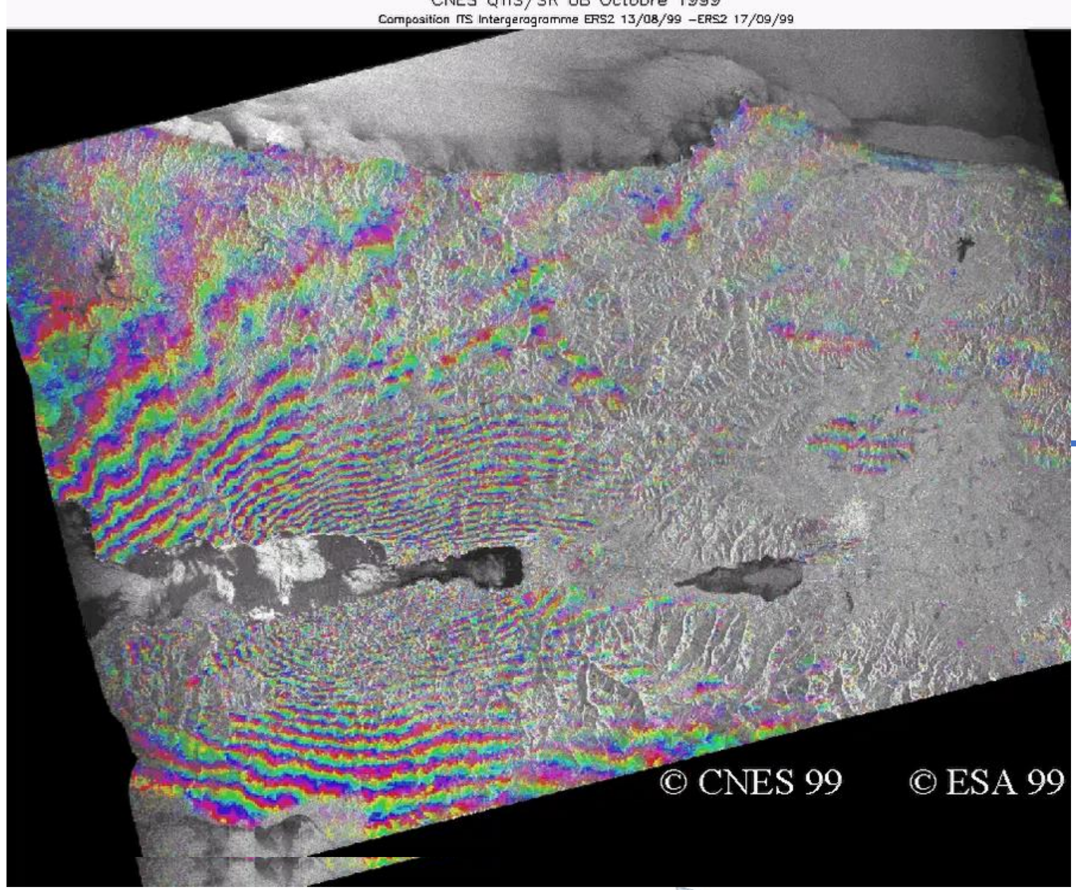
5- Analogy to Decision Making in Brain Connectome (Generalization of ML Roadmap):

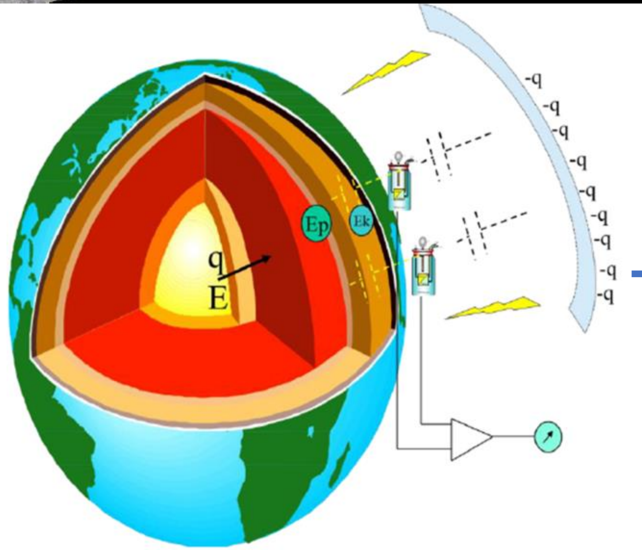




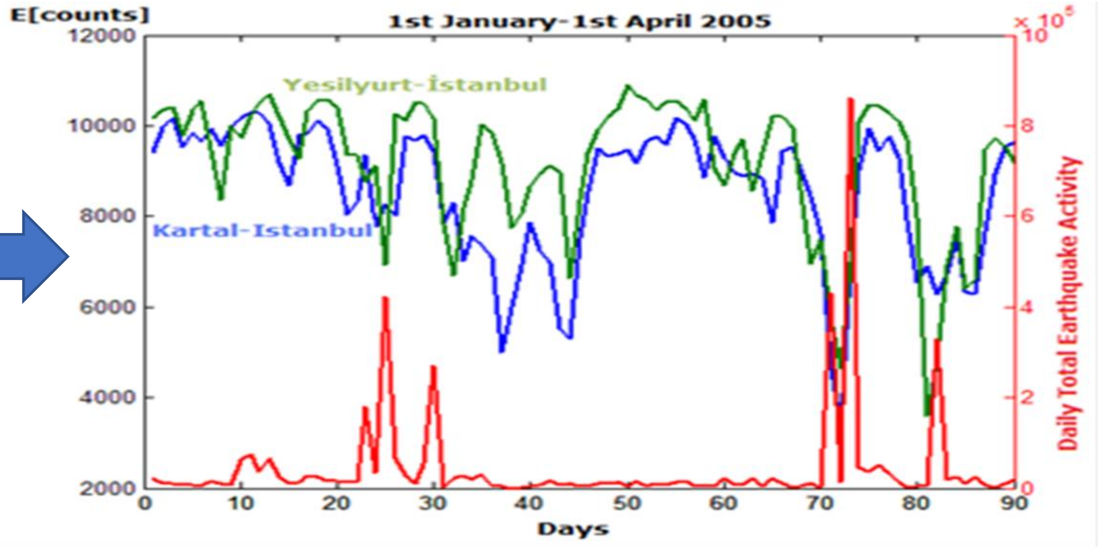
Fusion outcomes base on Artificial General Intelligence Roadmap:

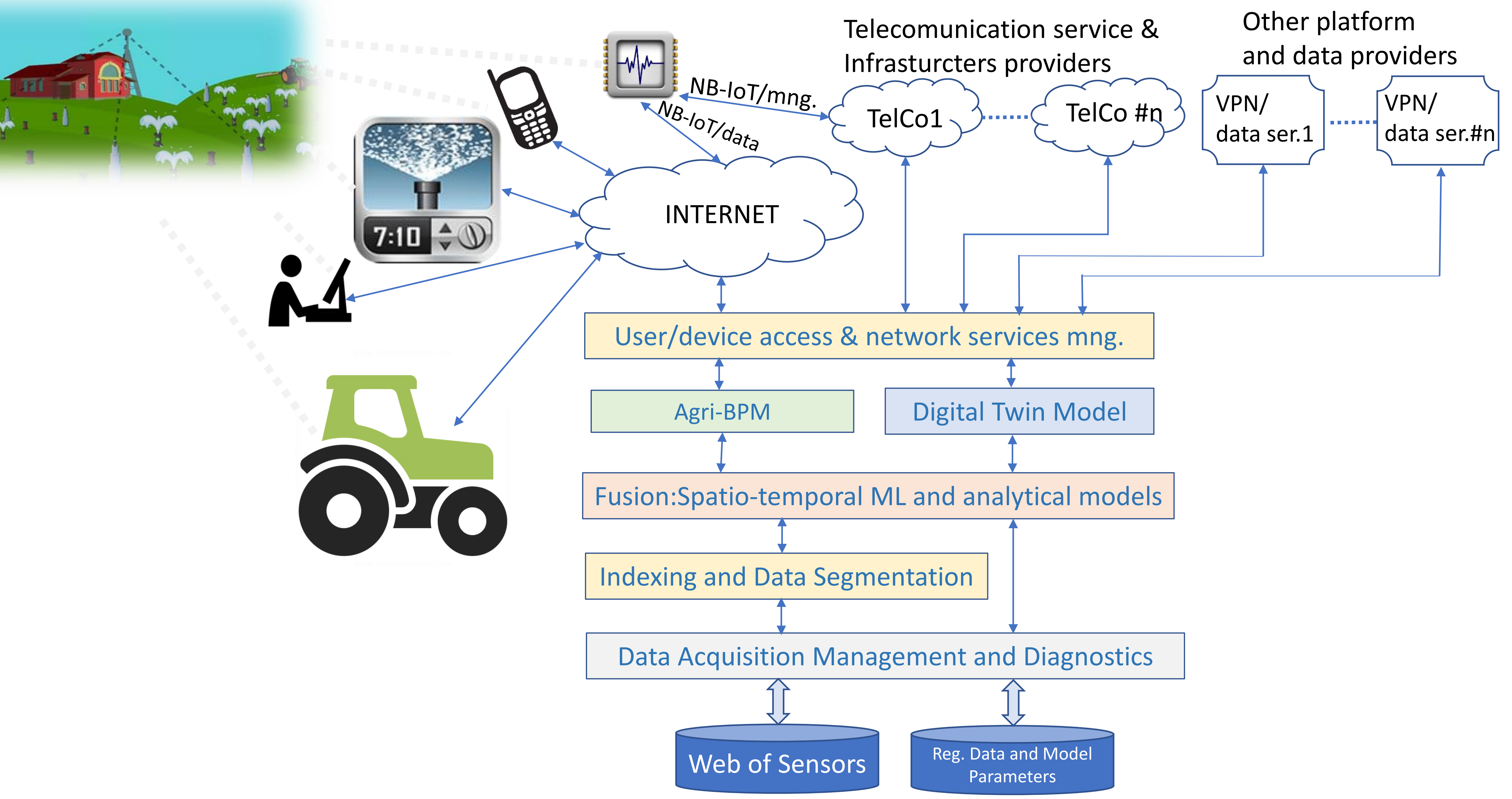
Risk management
GDP estimation
Energy production
Analytics for mining
Economic growthrate estimation
Urban management
Smart cities
Resource management
……
unlimited





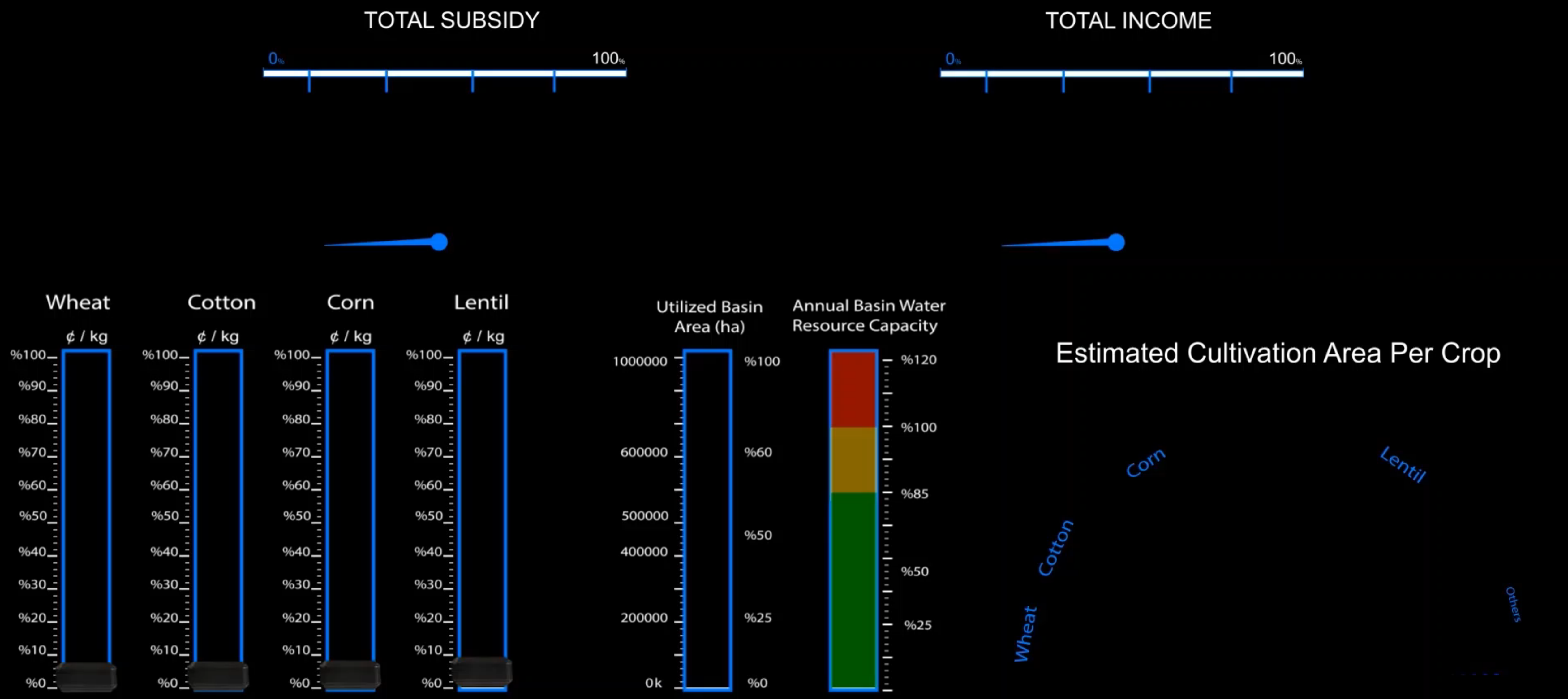
AI Fusion



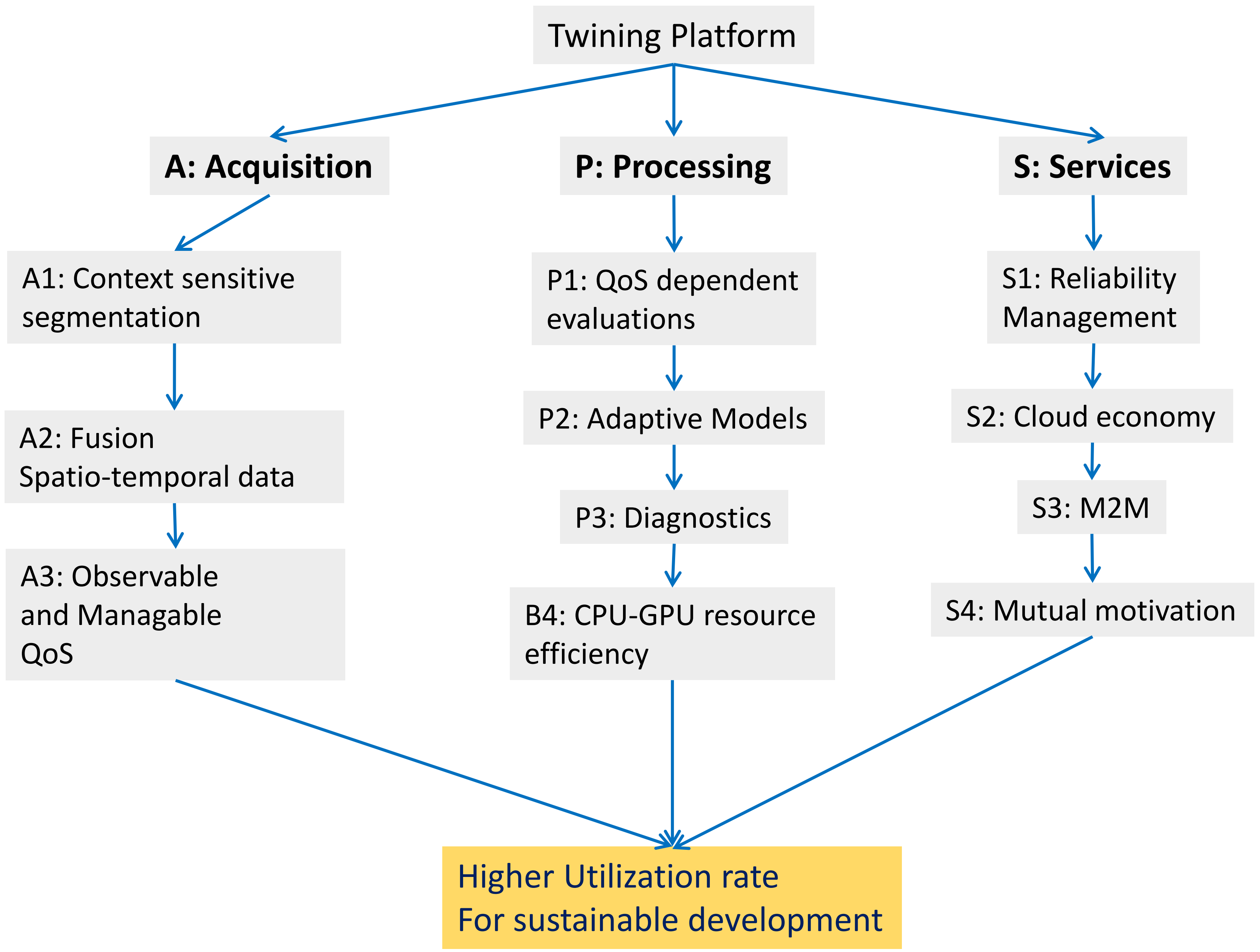


How to convert AI fusion based Digital Twinning into Services: PaaS , DaaS

Subsidy - Crop Pattern Management Panel



Platform in Digital Twinning ?



Conclusions:

- Overfitting management is the primary strategy in big RS data environment
- “Accuracy as a state” requires near-real-time accuracy and Tolerance computation
- Reference Network is necessary in platform scenarios besides individual sets
- PECNET minimizes overfitting in Artificial Intelligence on RS data
- Context Awareness in ML improves performance against non-linearity
- PaaS
- Conintual Learning must be supported against time variance of the system
- Orthogonal feature extraction can be optimized with PECNET
- Stochastic features can be decoded through cortical coding networks
- Artificial General Intelligence and Neuromorphism must be rec. for Singularity
- DaaS must take part in govermentlal subsidies at economic growth fields
- Digital Twinning is the feasible convergence roadmap for nowcasting and forecasting

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TEŞEKKÜRLER

THANK YOU

谢谢

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