

Data Harmonization for Crop Simulation: the ICASA/AgMIP Approach

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EXPERIMENTAL PROCEDURE

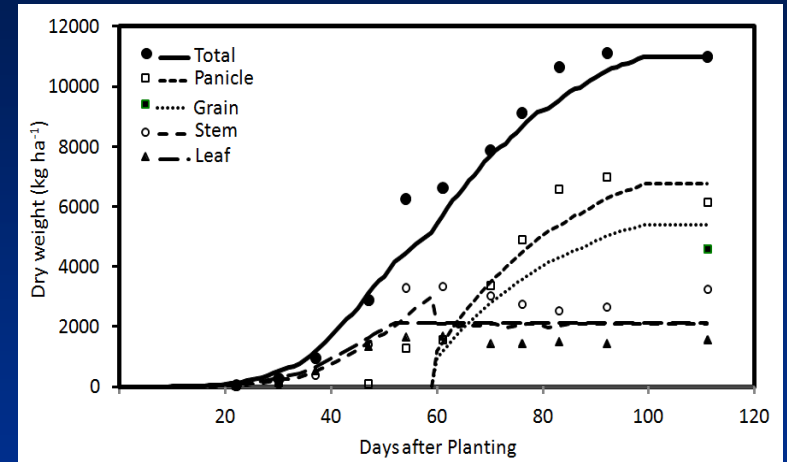
To determine the influence of leaf area on grain yield and to study the contribution of individual leaves to seed yield, various leaf removal treatments were inflicted in a planting of Midland grain sorghum at the late boot stage in 1958 and 1959. The treatments were: check (no defoliation), complete defoliation, and alternate (every other leaf removed) defoliation. In addition, certain individual leaves were left on otherwise completely defoliated plants. Leaves numbered 1 (flag leaf), 3, 5, 7, and 9 were left on each plant in these treatments. The resulting 8 treatments were established in a randomized complete block experiment with 3 replications in 1958 and 4 in 1959. Each plot consisted of three 18-foot rows with the inside 15 feet of the center row harvested for yield. A uniform spacing of 6 inches between plants in 40-inch rows was used. Heads were cut, air dried, threshed, and subsampled for weight per 200 seeds. The number of seeds per head was inferred from seed weight and mean head weight data for each plot.

A second experiment involved removing approximately half the leaf area from grain sorghum plants at boot and anthesis stages



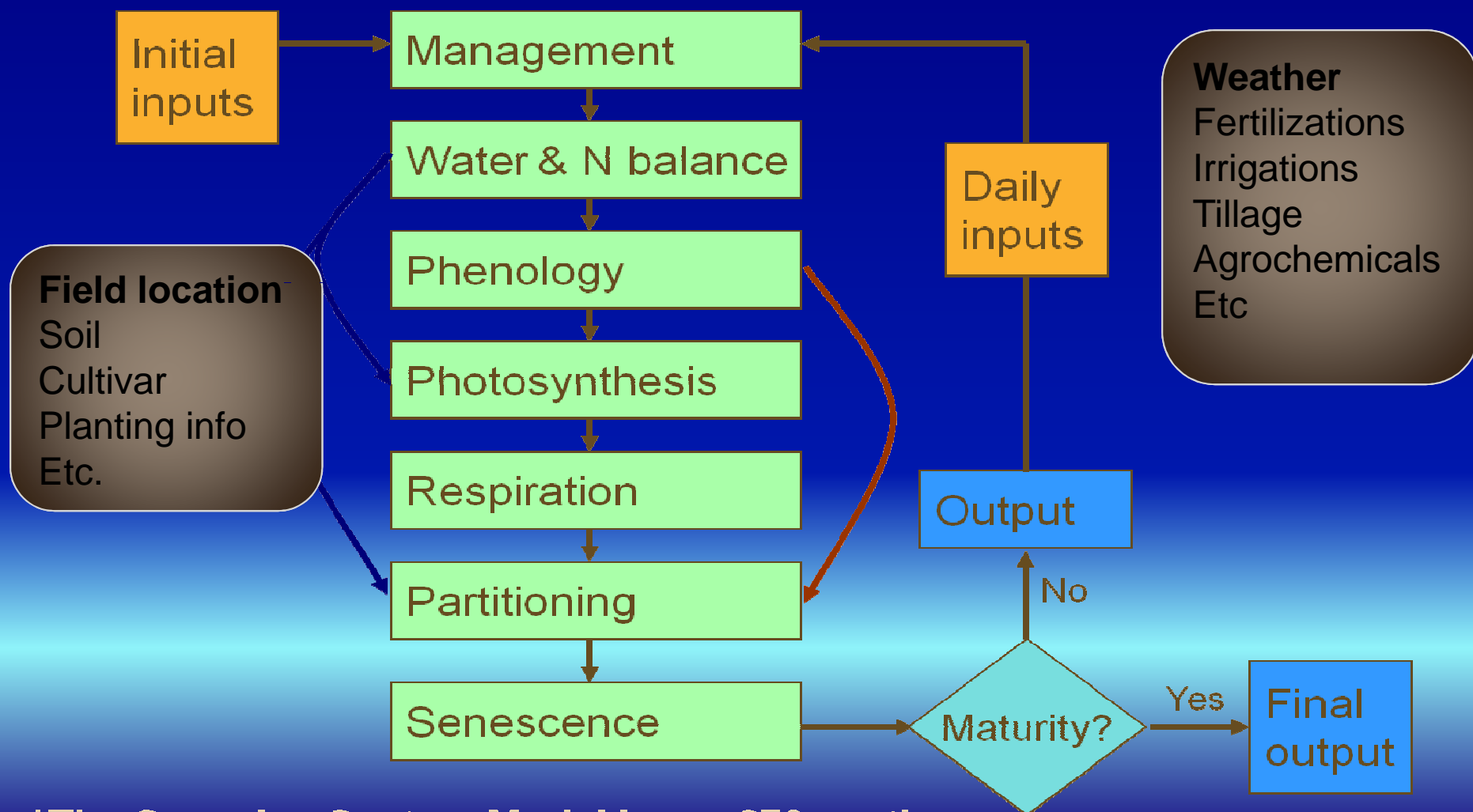
Crop simulation models

- “Ecophysiological models”
- Process-based
 - Light interception
 - Photosynthesis vs. respiration
 - Partitioning
 - Water & nutrient balances
- Complete life cycle of annual crops
- 50 years old: C.T. de Wit, R.S. Loomis
- Used for: crop management, plant breeding, *ex ante* impact assessment, futures trading, etc.
- Examples: CERES, EPIC, APSIM, ecosyst, CSM, etc.



Crop modeling requires diverse, accurate & abundant data

Simplified* flow diagram of an ecophysiological model



***The Cropping System Model has > 270 routines**

ICASA Standards

ICASA: Int. Consortium for Agricultural Systems Applications

Goal: Standards provide a reliable and flexible structure for ...

- Documenting field experiments
 - Environment: soils & weather
 - Crop management
 - Phenotypic responses
- Specifying realistic conditions for dynamic other applications.

Origin: minimum dataset

“agrotechnology transfer”

- Henry Nix
- 1983 ICRISAT workshop

PN-ARR-336 '84
ISBN=30739
Proceedings of the
International Symposium on
Minimum Data Sets
for Agrotechnology Transfer

ICRISAT Center
Patancheru, India
21–26 March 1983

Minimum Data Sets for Agrotechnology Transfer

Henry A. Nix*

Abstract

Prescription of appropriate technologies at farm level, at the transfer site, demands a systems understanding of the land, labor, capital, and management resources of the individual farmer. If it were possible to predict the performance of any crop production system at any location given a specified minimum set of crop-site-weather-management data, then it would be possible to prescribe appropriate technologies at the level of the farmer and his farm. It is argued that this is an ultimate and attainable objective of agricultural research, but only if there is a shift in emphasis away from reductionist and analytical research to holistic and systems-based research.

A systems-based research strategy centers on balanced development of two interactive



- Incorporate state-of-the-art climate products as well as crop and agricultural trade model improvements in coordinated regional and global assessments of future climate impacts
- Include multiple models, scenarios, locations, crops and participants to explore uncertainty and impact of data and methodological choices
- Collaborate with regional experts in agronomy, economics, and climate to build strong basis for applied simulations addressing key climate-related questions
- Improve scientific and adaptive capacity for major agricultural regions in the developing and developed world
- Develop framework to identify and prioritize adaptation strategies
- Link to key on-going efforts with numerous partners globally,

AgMIP data interoperability

- AgMIP ensemble modeling activities required a flexible, extensible means of providing data to multiple models.
- Facilitate research collaboration, model intercomparison and model improvement
- Make data available under the Creative Commons Attribution license



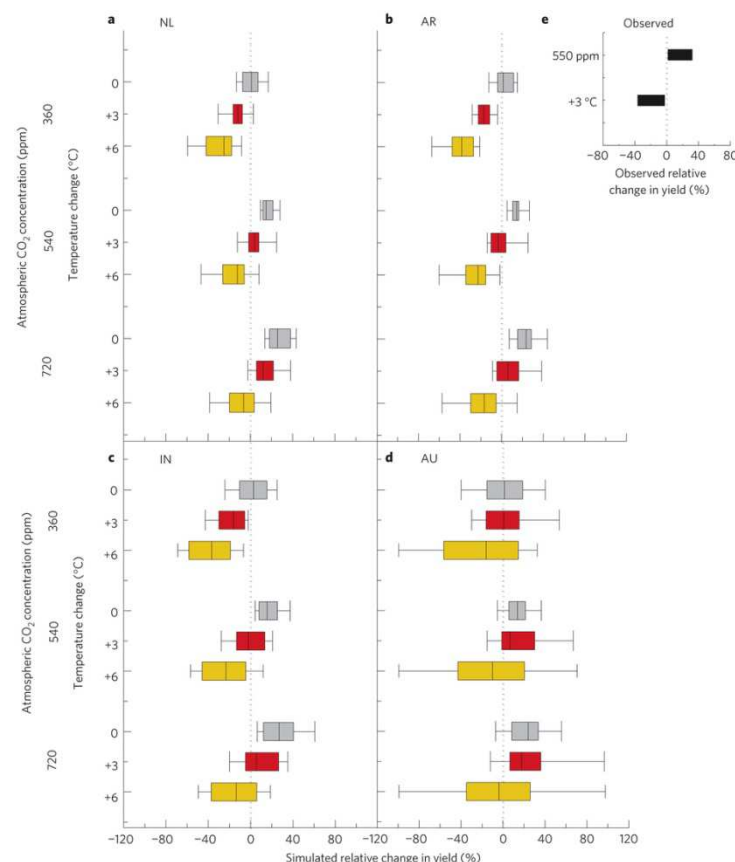
Wheat Pilot: 27 Simulation Models

Asseng et al., 2013
Uncertainty in simulating wheat yields
under climate change
Nature Climate Change

“This study . . . breaks new ground in discriminating between the uncertainties ascribed to crop models and those due to ensemble climate model projections.

Timothy R. Carter
Nature Climate Change News
and Views August 28, 2013

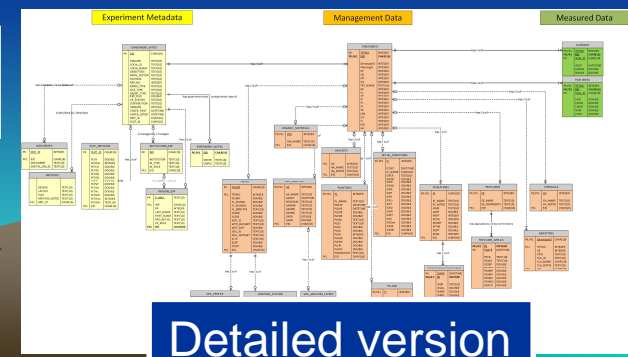
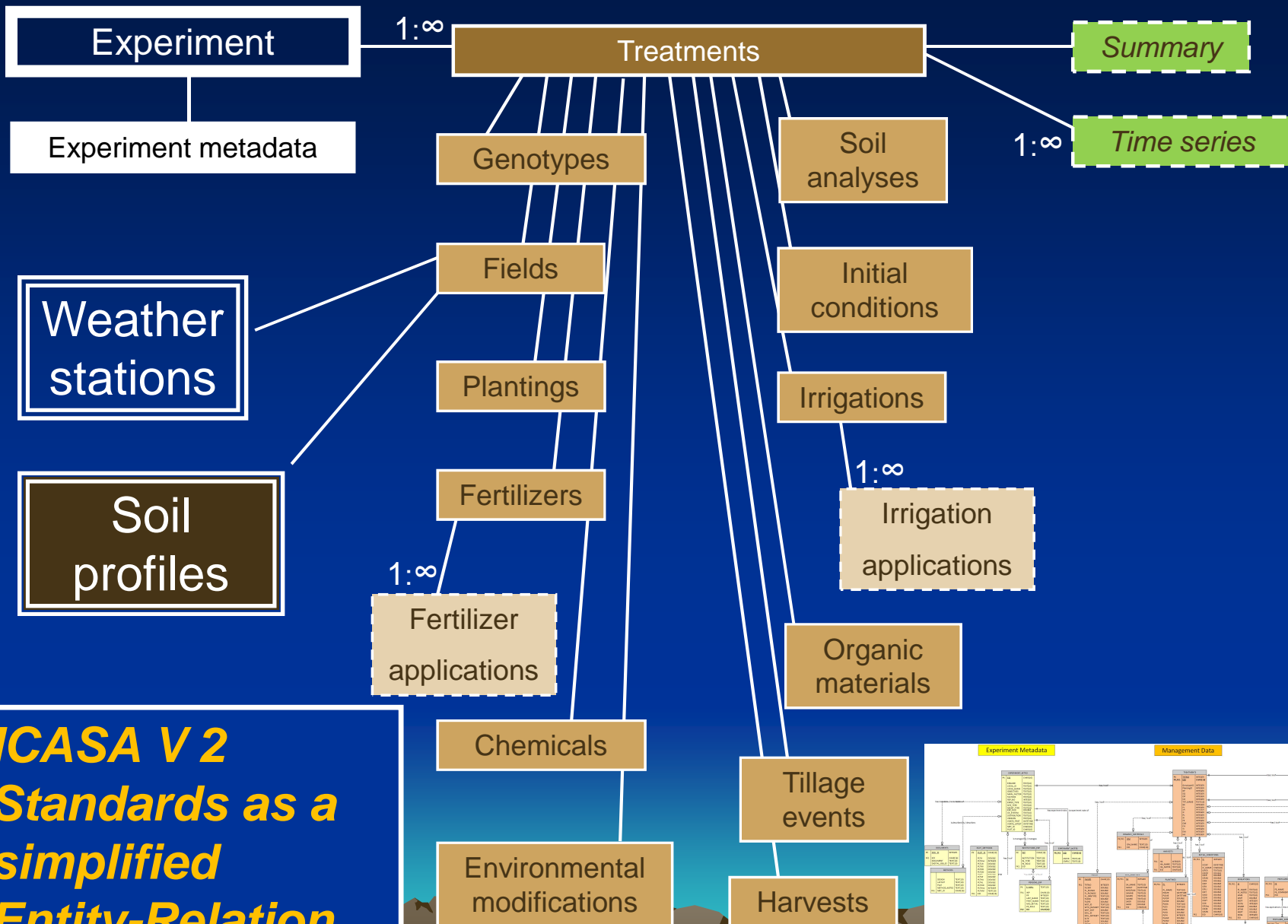
Responses to high temperature and high CO₂ still remain significant uncertainties



Metadata

Management Data

Measured data



ICASA V 2
Standards as a
simplified
Entity-Relation
Model

“Treatments” section is the key!

FACTOR LEVELS section links management & field conditions

```

$MANAGEMENT
*TREATMENTS
@TRTNO RP SQ OP CO TRT_NAME..... GE FL SA IC PL IR FE OM CH TI EM HA
  1  1  1  1  1 0N,dryland+weeds Rep1  1  1  1  1  1  0  0  1  1  1  1  1
  1  2  1  1  1 0N,dryland+weeds Rep2  1  1  1  1  1  0  0  2  1  1  1  1
  1  0  1  1  2 0N,dryland+weeds  2  1  1  1  2  0  2  1  1  1  1  1
  2  0  1  1  1 180N,dryland  1  1  1  1  1  0  3  1  1  1  1  1
  3  0  1  1  1 0N,irrigated  1  1  1  1  1  1  0  1  1  1  1  1
  4  0  1  1  1 60N,irrigated  1  1  1  1  1  1  2  1  1  1  1  1
  5  0  1  1  1 180N,irrigated  1  1  1  1  1  1  3  1  1  1  1  1
  6  0  1  1  1 180N,irrig(dap)  1  1  1  1  1  2  3  1  1  1  1  1
  7  0  1  1  1 180N,irrig(automatic)  1  1  1  1  1  3  3  1  1  1  1  1
  7  0  2  1  1 RedClover Post-harvest  3  1  0  0  3  0  0  0  0  0  0  0
  7  0  2  2  1 RedClover2 Postharvest  4  1  0  0  4  0  0  0  0  0  0  0

*GENOTYPES
@ GE CRID CUL_ID CUL_NAME.... CUL_NOTES
  1  WHB IB0488 Newton Hard red winter,Central Plains
  2  GRW IB0001 Garytown Central Gt.Plains quackgrass
  3  RCL IB0001 Bigyield General double cut
  4  RCL IB0002 Earlywonder Single cut

*FIELDS
@ FL ID_FIELD.. FL_NAME
  1 KSTASH0001 Research Park F105
@ FL FL_LOC_1 FL_LOC_2 FL_LOC_3
  1 USA KS Research Park, Ashland
@ FL FL_LAT FL_LONG FLELE FLSL FLSLL FLSLA FAREA FLOB FLLWR
  1 37.1167 -90.4521 85 20 200 90 226 -99 -99
  
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ICASA Standards: Structured plain text

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$EXPERIMENT:KANKSTS200401WHB
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-----FACTOR LEVELS-----
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CF FL GA IG PL IR PF QM QU TT VM WA
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*TIME COURSE
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@TRTNO	RP	SQ	OP	CO	YEAR	DOY	L#SD	LAI	P#AD	SWAD	GWAD	LWAD	CWAD	PWAD	SHAD	SH%D	SLAD
1	0	1	1	1	1986	289	5.1	1.12	0.0	104.0	0.00	250.0	354.0	0.00	0.00	.	446.8
1	0	1	1	1	1986	289	5.1	0.83	0.0	98.00	0.00	242.0	340.0	0.00	0.00	.	342.4
1	0	1	1	1	1986	289	5.0	0.58	0.0	64.00	0.00	152.0	216.0	0.00	0.00	.	379.2
1	0	1	1	1	1986	289	4.8	0.69	0.0	78.00	0.00	204.0	282.0	0.00	0.00	.	337.2
1	0	1	1	1	1986	296	.	2.21	0.0	402.0	0.00	790.0	1192	0.00	0.00	.	279.3
1	0	1	1	1	1986	296	.	1.62	0.0	304.0	0.00	556.0	860.0	0.00	0.00	.	292.0
1	0	1	1	1	1986	296	.	1.43	0.0	202.0	0.00	444.0	646.0	0.00	0.00	.	321.0
1	0	1	1	1	1986	296	.	1.35	0.0	154.0	0.00	438.0	592.0	0.00	0.00	.	308.2
1	0	1	1	1	1986	305	.	5.38	0.0	1086	0.00	1214	2300	0.00	0.00	.	442.9
1	0	1	1	1	1986	305	.	4.46	0.0	1004	0.00	1128	2132	0.00	0.00	.	395.2
1	0	1	1	1	1986	305	.	4.52	0.0	826.0	0.00	1062	1888	0.00	0.00	.	425.3
1	0	1	1	1	1986	305	.	4.91	0.0	988.0	0.00	1182	2170	0.00	0.00	.	415.5
1	0	1	1	1	1986	311	.	5.67	68.0	1312	0.00	1296	2612	4.00	4.00	0.00	437.8
1	0	1	1	1	1986	311	.	4.55	122.0	1580	0.00	1728	3318	10.00	10.00	0.00	263.3
1	0	1	1	1	1986	311	.	1.42	36.0	1016	0.00	1008	2026	2.00	2.00	0.00	140.4
1	0	1	1	1	1986	311	.	3.93	60.0	1286	0.00	1566	2856	4.00	4.00	0.00	250.9
1	0	1	1	1	1986	316	.	7.25	488.0	1888	0.00	1658	3792	246.0	246.0	0.00	437.3
1	0	1	1	1	1986	316	.	6.35	492.0	1962	0.00	1678	3894	254.0	254.0	0.00	378.7

ICASA Standards: Implementations

Digital formats: AGNOSTIC

- Plain text (specific syntax)
- Spreadsheet
- Relational database
- noSQL database using JSON objects

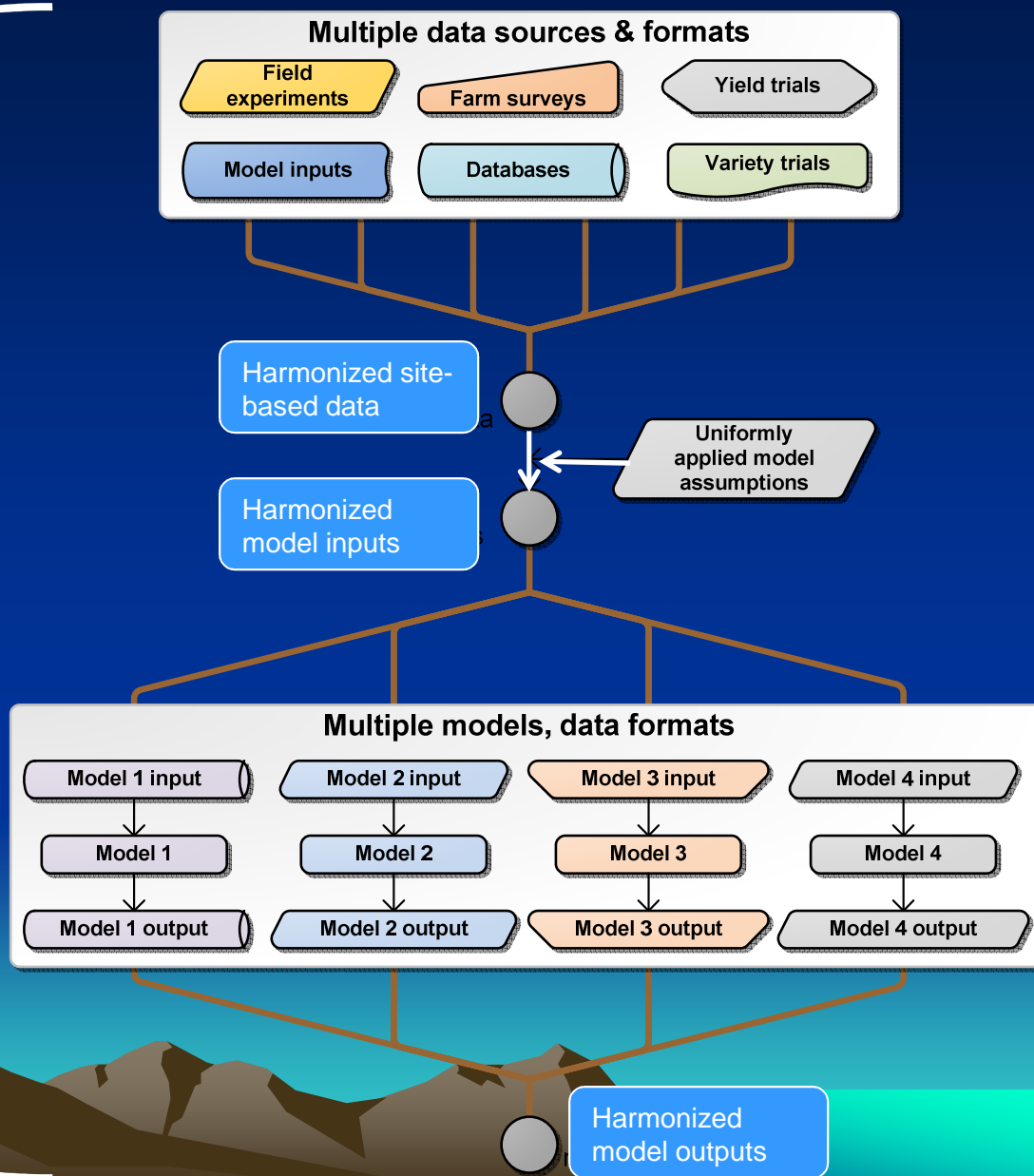
***Architecture** and **vocabulary** are what determine compliance!*

Emphasis is on describing single experiments accurately.



The ICASA Standards provide the foundation for harmonizing data from different sources

AgMIP and ICASA



ICASA/AgMIP template

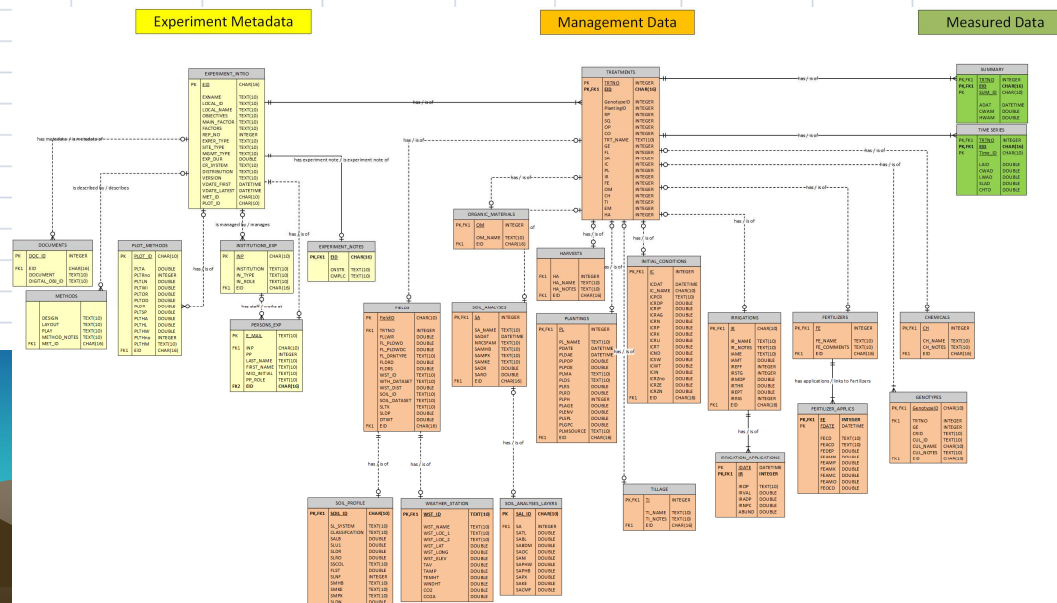
HSC-sample_4.5.xlsx - Microsoft Excel													
G90													
	A	B	C	D	E	F	G	H	I	J	K	L	M
1	! Field Experiment Data Template						v2.3	2012-08-28					
2													
3	! Legend	Legend:											
4	!	Symbol	Location	Description									
5	!	!	Column 1	Comment									
6	!	#	Column 1, headers	Summary data variable names									
7	!	%	Column 1, headers	Series data variable names (time series or soil layer data)									
8	!	Unique id (1, 2, A, B, ...)	First field of data	Relational data requires unique id to show relationships between summary and series sections of data									
9	!	*	First field of data	Complete data (one line per experiment)									
10													
11	! Date format	NOTE: Dates must be in ISO-compliant yyyy-mm-dd format.											
12	!	When exporting to csv format, please verify that the date format was preserved.											
13	!	To format dates in this format, select "Custom" format and type in "yyyy-mm-dd" under "Type".											
14	!	Or use the Format Painter to copy the format from another field.											
15													
16	! Metadata / Field Data Section												
17													
18	! Definitions	Suite name - grouping of experiments	Experiment name	treatment name			Location	Duration of experiment	Latitude	Longitude	Field elevation	Weather station id	Soil id
19	! Units						year	decimal degrees	decimal degrees	m			
20	#	suite_name	exname	TRT_NAME	institution	site_name	local_name	exp_dur	fl lat	fl long	flele	wst_id	soil_id
21	1	HSC	ARMA0701	13MAR07 C pl=	USDA ARS, Aric Maricopa Agr	Maricopa, A		2	33.069	-114.53	361	AZ00	AZMC920001
22	2	HSC	ARMA0701	13MAR07 C pl=	USDA ARS, Aric Maricopa Agr	Maricopa, A		2	33.069	-114.53	361	AZ00	AZMC920001
23	3	HSC	ARMA0701	13MAR07 C pl=	USDA ARS, Aric Maricopa Agr	Maricopa, A		2	33.069	-114.53	361	AZ00	AZMC920001
24													
25	! Initial Conditions Section												
26													
27	! Definitions	Initial conditions date	Previous crop code	Initial surface residue	Initial root residue	Initial residue N conc							

ICASA/AgMIP template

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
37	! Management Events Section													
38														
39	! Definitions	Type of event		Date of event	yyyy-mm-dd	Crop ID	Wheat	Cultivar ID	text	Additional data about cultivar	text	Plant population	#/m2	sp
40	1 Event	Planting	pdate	2007-03-13	CRID	WHB	CUL_ID	Yecora Ro	CUL_NOTES	Spring wheat	PLPOP		265	PLRS
41	2 Event	Planting	pdate	2007-03-13	CRID	WHB	CUL_ID	Yecora Ro	CUL_NOTES	Spring wheat	PLPOP		320	PLRS
42	3 Event	Planting	pdate	2007-03-13	CRID	WHB	CUL_ID	Yecora Ro	CUL_NOTES	Spring wheat	PLPOP		276	PLRS
43														
44	! Definitions	Type of event	Date of event	yyyy-mm-dd	Irrigation type code	Sprinkler	Irrigation amount	mm						
45	1 Event	Irrigation	idate	2007-03-19	IROP	IR005	IRVAL	94.1						
46	1 Event	Irrigation	idate	2007-03-27	IROP	IR005	IRVAL	9.7						
47	1 Event	Irrigation	idate	2007-03-28	IROP	IR005	IRVAL	10						
48	1 Event	Irrigation	idate	2007-04-04	IROP	IR005	IRVAL	32.3						
49	2 Event	Irrigation	idate	2007-03-21	IROP	IR005	IRVAL	94.1						
50	2 Event	Irrigation	idate	2007-03-27	IROP	IR005	IRVAL	8.6						
51	2 Event	Irrigation	idate	2007-03-28	IROP	IR005	IRVAL	8.5						
52	2 Event	Irrigation	idate	2007-04-04	IROP	IR005	IRVAL	31.1						
53	3 Event	Irrigation	idate	2007-03-21	IROP	IR005	IRVAL	94.1						
54	3 Event	Irrigation	idate	2007-03-27	IROP	IR005	IRVAL	7.7						
55	3 Event	Irrigation	idate	2007-03-28	IROP	IR005	IRVAL	7.9						
56	3 Event	Irrigation	idate	2007-04-04	IROP	IR005	IRVAL	32.7						
57														
58	%	Type of event	Date of event	yyyy-mm-dd	Fertilizer type code	Fertilizer type value	Fertilizer application code	Fertilizer application value	Incorporation depth	cm	Fertilizer N	kg[N]/ha		
59	1 Event	Fertilizer	fedate	2007-03-13	FECD	FE007	FEACD	AP002	FEDEP	15	FEAMN		51	
60	1 Event	Fertilizer	fedate	2007-04-13	FECD	FE010	FEACD	AP005	FEDEP	15	FEAMN		57	
61	1 Event	Fertilizer	fedate	2007-04-26	FECD	FE010	FEACD	AP005	FEDEP	15	FEAMN		56	
62	1 Event	Fertilizer	fedate	2007-05-11	FECD	FE010	FEACD	AP005	FEDEP	15	FEAMN		56	
63	2 Event	Fertilizer	fedate	2007-03-13	FECD	FE007	FEACD	AP002	FEDEP	15	FEAMN		51	
64	2 Event	Fertilizer	fedate	2007-04-13	FECD	FE010	FEACD	AP005	FEDEP	15	FEAMN		55	
65	2 Event	Fertilizer	fedate	2007-04-26	FECD	FE010	FEACD	AP005	FEDEP	15	FEAMN		56	
66	2 Event	Fertilizer	fedate	2007-05-11	FECD	FE010	FEACD	AP005	FEDEP	15	FEAMN		56	
67	3 Event	Fertilizer	fedate	2007-03-13	FECD	FE007	FEACD	AP002	FEDEP	15	FEAMN		51	
68	3 Event	Fertilizer	fedate	2007-04-13	FECD	FE010	FEACD	AP005	FEDEP	15	FEAMN		55	
69	3 Event	Fertilizer	fedate	2007-04-26	FECD	FE010	FEACD	AP005	FEDEP	15	FEAMN		56	
70	3 Event	Fertilizer	fedate	2007-05-11	FECD	FE010	FEACD	AP005	FEDEP	15	FEAMN		56	
71														

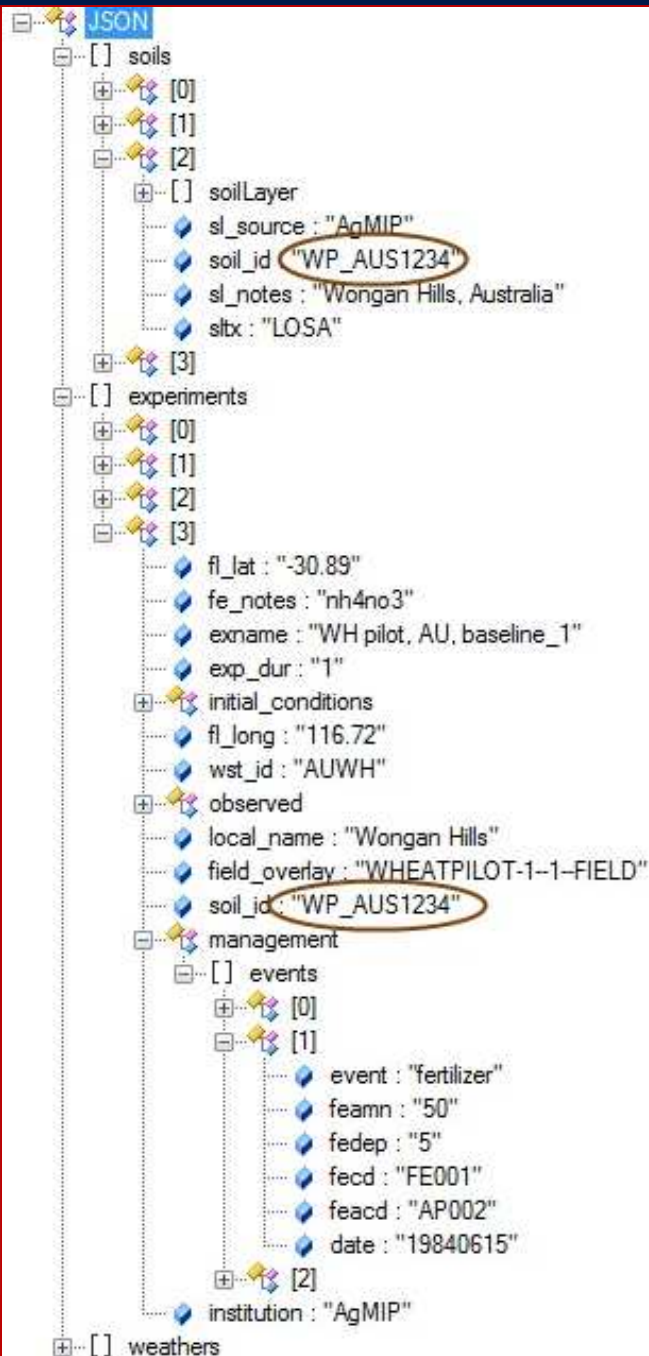
ICASA/AgMIP template

69	3	Event	Fertilizer	fedate	2007-04-26	FECD	FE010	FEACD	AP005	FEDEP	15	FEAMN
70	3	Event	Fertilizer	fedate	2007-05-11	FECD	FE010	FEACD	AP005	FEDEP	15	FEAMN
71												
72	! Observed Data Section											
73												
74	! Summary information											
75	! Definitions	Emergence date	Anthesis date	Physiological maturity date	Harvested yield	Above ground biomass	Treatment name					
76	! Units	yyyy-mm-dd	yyyy-mm-dd	yyyy-mm-dd	kg/ha	kg/ha	text					
77	#	PLDAE	ADAT	MDAT	HWAH	CWAM	!					
78	1	2007-03-27	2007-05-10	2007-06-04	5751	12602	13MAR07 C pl= 6					
79	2	2007-03-27	2007-05-12	2007-06-01	2998	6964	13MAR07 C pl= 8					
80	3	2007-03-27	2007-05-12	2007-06-04	6307	15524	13MAR07 C pl= 10					
81												
82	! Time Series											
83	! Definitions	Observation date	Above ground biomass, dry	Grain dry weight								
84	! Units	yyyy-mm-dd	kg/ha	kg/ha								
85	%	date	cwad	GWAD								
86	1	2007-04-25	1486									
87	1	2007-05-21	8953									
88	1	2007-06-06	12602	5751								
89	2	2007-04-25	1525									
90	2	2007-05-21	6438									
91	2	2007-06-06	6964	2998								
92	3	2007-04-25	1837									
93	3	2007-05-21	7493									
94	3	2007-06-06	15524	6307								
95												



ACE Harmonized data format

- Key-value pairs, (where key = ICASA variable) stored in JSON objects
- Non-relational schema conforms to highly irregular data from diverse sources
- Efficient, flexible, open ended storage
- “buckets” for experiment / field, soils, and weather data
- Sub-structures for initial conditions, management events, soil layer data, etc.



ICASA/AgMIP list of terms – From a knowledge management perspective, what is it?

Candidate terms

- Ontology
- Data dictionary
- Thesaurus
- Glossary
- Controlled vocabulary

Content

- Name & synonyms
- Meaning
- Hierarchy of relations
- Units
- Data type
- Validation criteria

Wikipedia: A **data dictionary**, as defined in the *IBM Dictionary of Computing*, is a "centralized repository of information about data such as meaning, relationships to other data, origin, usage, and format."



ICASA/AgMIP Data Dictionary: Next Steps

- Need to provide the Dictionary with a more intelligent interface than Google Sheets:
 - Searchable (not “Ctrl-F” among spreadsheets)
 - Allow users to submit questions and suggest terms
 - Hide information used only by developers
- Expand to meet community needs:
 - Sub-daily time scales
 - Life Cycle Analysis
 - Pest and disease evaluations Protocols/assays
 - More complete information on variables
- Harmonize with other resources
 - GRACEnet/REAP (USDA research databases)
 - CropOntology.org and AgTrials



The ICASA Data Dictionary:

www.tinyurl.com/licasa-mvl

	A	B	C	D	E	F	G
1	Variable Name	Description	Unit or	Dataset	Subset	Group	Sub-Group
142	soil_idenfier	Soil identifier	code	EXPERIMENT	MANAGEMENT	FIELDS	
143	soil_file	File containing relevant soil profile description	text	EXPERIMENT	MANAGEMENT	FIELDS	
144	water_table_depth	Water table depth	cm	EXPERIMENT	MANAGEMENT	FIELDS	
145	field_notes	Field, short notes	text	EXPERIMENT	MANAGEMENT	FIELDS	
146	field_soil_texture	Field observed soil texture	code	EXPERIMENT	MANAGEMENT	FIELDS	
147	soil_analysis_date	Soil analysis date	date	EXPERIMENT	MANAGEMENT	SOIL ANALYSES	
148	id	id		EXPERIMENT	MANAGEMENT	SOIL ANALYSES	
149	soil_analysis_level	Soil analysis, treatment level identifier	number	EXPERIMENT	MANAGEMENT	SOIL ANALYSES	
150	soil_analysis_name	Soil analysis name	text	EXPERIMENT	MANAGEMENT	SOIL ANALYSES	
151	soil_family_NRCS_system	Soil family, NRCS system	text	EXPERIMENT	MANAGEMENT	SOIL ANALYSES	
152	soil_analysis_year	Soil analysis year	year	EXPERIMENT	MANAGEMENT	SOIL ANALYSES	
153	soil_analysis_day	Soil analysis day of year or days after planting	day	EXPERIMENT	MANAGEMENT	SOIL ANALYSES	
154	soil_analys_meth_pH_buff	Soil anlysis method for pH in buffer solution	code	EXPERIMENT	MANAGEMENT	SOIL ANALYSES	
155	soil_anal_meth_P_extract	Soil analysis method for P extraction	code	EXPERIMENT	MANAGEMENT	SOIL ANALYSES	
156	soil_anal_meth_exch_K	Soil analysis method for exchangeable	code	EXPERIMENT	MANAGEMENT	SOIL ANALYSES	
157	drainage_rate_per_day	Drainage rate as fraction per day	1/d	EXPERIMENT	MANAGEMENT	SOIL ANALYSES	
158	runoff_curve_no_SCS	Runoff curve no. (Soil Conservation Service)	number	EXPERIMENT	MANAGEMENT	SOIL ANALYSES	
159	id	id		EXPERIMENT	MANAGEMENT	SOIL ANALYSES	SOIL_ANALYSES_LAYERS
160	soil_analysis_level	Soil analysis, treatment level identifier linkage	number	EXPERIMENT	MANAGEMENT	SOIL ANALYSES	SOIL_ANALYSES_LAYERS
161	soil_layer_top_depth	Soil layer depth to upper boundary of sample (top)	cm	EXPERIMENT	MANAGEMENT	SOIL ANALYSES	SOIL_ANALYSES_LAYERS
162	soil_layer_base_depth	Soil layer depth to lower boundary of sample (bottom)	cm	EXPERIMENT	MANAGEMENT	SOIL ANALYSES	SOIL_ANALYSES_LAYERS
163	soil_bulk_dens_moist	Soil bulk density, moist, determined on field sample	g/cm3	EXPERIMENT	MANAGEMENT	SOIL ANALYSES	SOIL_ANALYSES_LAYERS
164	organic_carbon_conc	Organic carbon	%	EXPERIMENT	MANAGEMENT	SOIL ANALYSES	SOIL_ANALYSES_LAYERS
165	soil_N_conc_total	Nitrogen, total soil, total	%	EXPERIMENT	MANAGEMENT	SOIL ANALYSES	SOIL_ANALYSES_LAYERS
166	pH_in_water	pH of soil in water, from in-field sample	number	EXPERIMENT	MANAGEMENT	SOIL ANALYSES	SOIL_ANALYSES_LAYERS
167	pH_in_buffer	pH of soil measured in buffer solution, from in-field sample	number	EXPERIMENT	MANAGEMENT	SOIL ANALYSES	SOIL_ANALYSES_LAYERS
168	phosphorus_extractable	Phosphorus, extractable	mg/kg	EXPERIMENT	MANAGEMENT	SOIL ANALYSES	SOIL_ANALYSES_LAYERS
169	potassium_exchangeable	Potassium, exchangeable	cmol/kg	EXPERIMENT	MANAGEMENT	SOIL ANALYSES	SOIL_ANALYSES_LAYERS
170	soil_compac_fact_by_lyr	Soil compaction factor by layer (0 to 1 scale)	number	EXPERIMENT	MANAGEMENT	SOIL ANALYSES	SOIL_ANALYSES_LAYERS
171	soil_compac_fact_by_lyr	Soil compaction factor by layer (0 to 1 scale)	number	EXPERIMENT	MANAGEMENT	SOIL ANALYSES	SOIL_ANALYSES_LAYERS

Climate_codes

Other_codes

Pest_codes

Form Responses 1

Form Responses 2

Sheet1