PAPER UC1031 of 2006

TITLE:
Creating Time Series of Land-Cover Maps with Model Builder

ABSTRACT:
The major goal of the Tulare Land Cover Classification System (TLCCS) is to develop a consistent set of land-cover maps, spanning the period 1986 into the future. Using ArcGIS Model Builder, Tulare County has generated a detailed time series of land-cover maps by blending data from several sources. These maps will be used to monitor changes in land cover in a rural county experiencing rapid urban growth in the San Joaquin Valley. The TLCCS has been organized to maximize integration with other classification systems, such as those used by California's Farmland Monitoring and Mapping Program (FMMP), the California Department of Water Resources (DWR), and the United States Geological Survey's National Land Cover Database of 1992. The maps of the TLCCS are generated by blending information from these sources as well as the GIS PARCELS layer, which includes the Assessor's USE code for all parcels in the county.

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Report Summary:

Tulare County GIS has developed a consistent set of land cover maps, spanning the period 1986 (earliest Farmland Monitoring and Mapping Program (FMMP map) to the present. Intended uses for these maps include:

- To monitor changes in land cover, over time and space, in order to measure the 'rate of change' (and to determine how much the 'rate of change' varies, over time and space);
- To monitor changes in land cover, over time and space, in order to measure the loss of farmland to urbanization and to other sources;
- To monitor changes in land cover for consistency with Master Plan policies;
- To provide a reliable source of data for estimating the number of dwelling units within any specified district for any specified year after 1986;
- To provide a reliable source of data for estimating the consumption of water (by urbanized development -or- by agriculture) within any specified district for any specified year after 1986;
- To provide a reliable source of data that can be used by various urban development simulation packages.

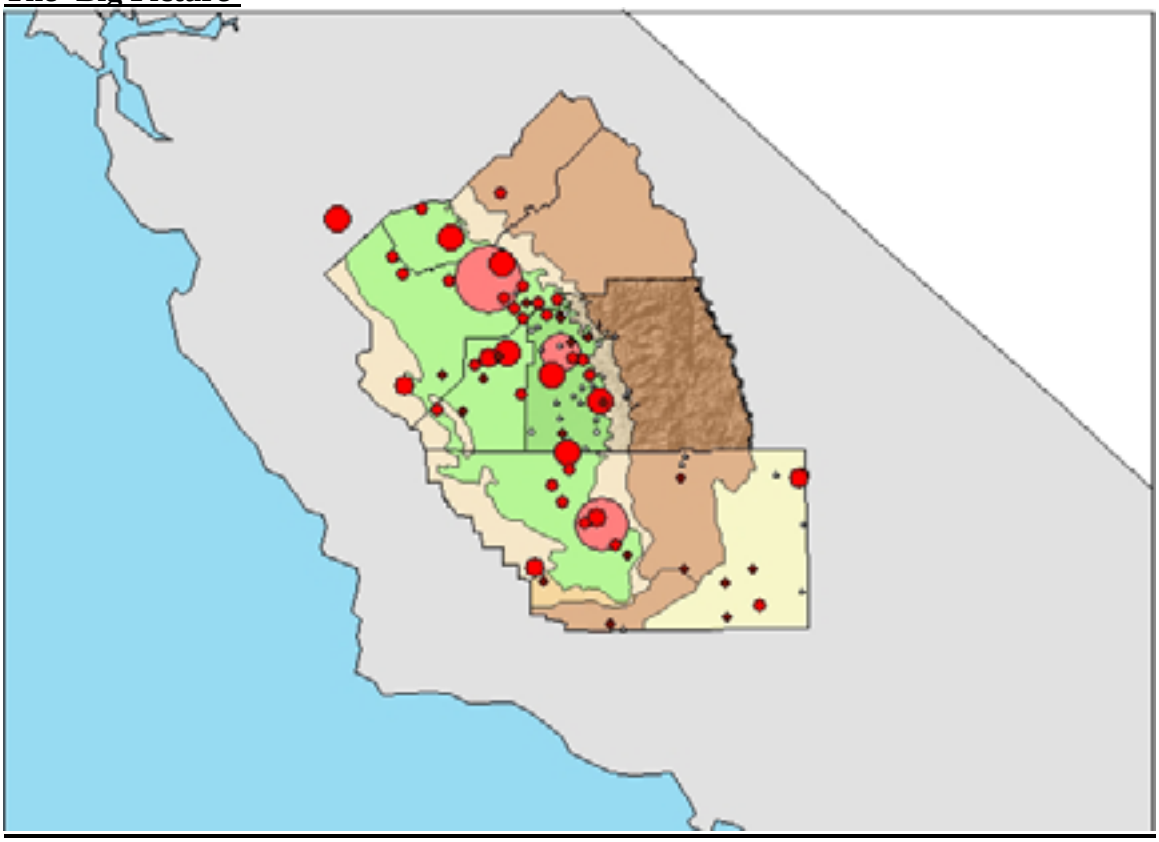
Tulare Land Cover Classification System (TLCCS) was created in order to maximize comparability with other classification systems, such as those used by California's Farmland Monitoring and Mapping Program (FMMP), the California Department of Water Resources (DWR), and the United States Geological Survey's National Land Cover Database of 1992. The maps of the TLCCS are generated by blending information from these sources as well as County Assessor's PARCELS, which includes the Assessor's [use] code for all parcels in the county.

GIS has successfully developed GIS tools which generate a time series (1986 – 2004) of detailed land cover maps covering the whole county. These tools could easily be adapted to generate time series of land cover maps for any county that has similar GIS data available (certainly every county in the San Joaquin Valley).

Two types of future activity are envisioned:

- Make the TLCCS and GIS model available to other counties and to universities in order that it may be subjected to critical peer review to identify potential flaws and enhancements.
- Apply the data of this time series to actual tasks, such as preparing TCAG's UPlan Land Use Model, preparing data to update TCAG's transportation model, and other specific monitoring tasks.

The 'Big Picture'



Tulare County (and the whole of the San Joaquin Valley) is expected to receive pressure to rapidly urbanize now that coastal California seems to be 'filled out' Urbanization in the San Joaquin Valley is subject to many constraints:

- Limits on the availability of water for urban users
- Air Quality concerns
- A need to preserve to agricultural lands (the richest, most productive soils/climate in the nation)
- A strong desire to preserve the rural/small town way of life

In order to provide timely and useful information to the county's Policy/Decision makers, TCAG requested GIS to develop the spatial data and analysis tools that would allow TCAG and county planners to monitor the location and extent of land use changes through out the county in order to:

- Monitor changes in land cover, over time and space, in order to measure the 'rate of change' (and to determine how much the 'rate of change' varies, over time and space);
- Monitor changes in land cover, over time and space, in order to measure the loss of farmland to urbanization and to other sources;
- Monitor changes in land cover for consistency with Master Plan policies;
- Provide a reliable source of data for estimating the number of dwelling units within any specified district for specified year after 1986;
- Provide a reliable source of data for estimating the consumption of water (by urbanized development -or- by agriculture) within any specified district for specified year after 1986;
- Provide a consistent source of data that can be used by various urban development simulation packages.

Past Effort (2001 - 2002)

Effort was focused on generating a time series of land use maps from Assessor's USE code from a quarterly series of PARCEL themes, using ArcView 3.x (Avenue Programming Language)

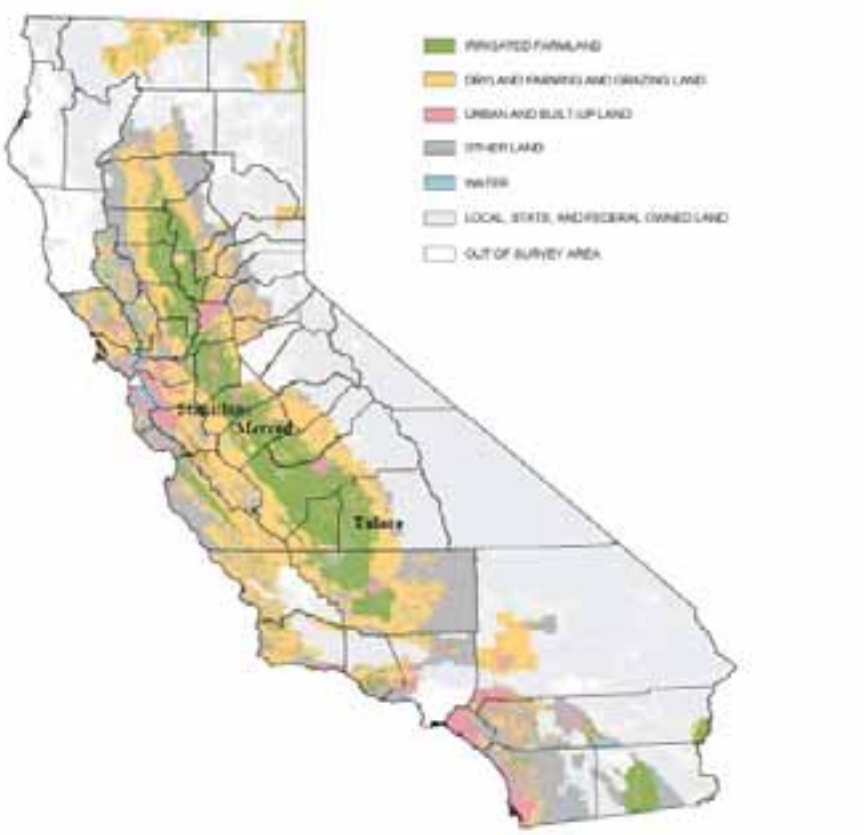
The lessons learned from this effort were:

- ArcView 3.x (Avenue Programming Language) was not suitable for a sustained modeling/development effort.
- GIS PARCELS yields too short a time series (no data prior to 1998) to be useful for many applications. (Rule of Thumb is that for every two years of past data, you can project one year into the future with some degree of confidence.)
- Assessor's USE code is good data for recently developed, taxable, small parcels that have only one USE. For parcels that do not satisfy these four conditions, the data is less reliable.
- It is not practical to do an analysis of change on a time series of polygons.
- The Land Use Classification used by GIS was 'ad hoc' and 'intuitively obvious': Residential, Commercial, Industrial, Perennial Ag, Annual Ag, Grazing, Natural, and Other. Too much fell into the 'other' category.

Current Effort (2005 - 2006)

Each of the deficiencies of the earlier effort has been addressed:

- ArcView 9.x has significantly improved tools for a sustained modeling/development effort (the Geoprocessing Model Builder and the Python programming language)
- Of the available data sources, FMMP maps provide the greatest time span (biannual, since 1986). FMMP maps contain systemic ambiguities that can only be resolved by using other data sources.



- Rather than relying on a single data source, several data sources were used: USGS digital elevation models (DEMs), USGS National Land Cover Data of 1992, California Department of Water Resources (DWR 1993 & 1999), California Monitoring and Mapping Program (biannual FMMP 1986 thru 2004), and Tulare County PARCELS (1998 to present). Each data source, depending on its original purpose, maps some data very well and other data less well. By compiling a map from several sources, it should be possible to obtain results that are better than any of the original sources.
- In order to compare/combine data from different sources, they need to be converted to a common format (GRID/pixel data rather than polygon/vector data) and a common map projection (California State Plane, Zone IV, NAD'83)
- In order to compare/combine data with different classification categories, it is necessary to convert the data to a common classification system. The Tulare Land Cover Classification System (TLCCS) was developed for that purpose.

A set of geoprocessing models has been created to convert the source data into a consistent time series of land cover maps spanning the period 1986 through 2004. (The 2006 FMMP map will not be available till 2008+/-.) This time series of TLCCS maps comes in two flavors:

- *The Basic Time Series* is generated from public data sources (FMMP, DWR, and USGS-NLCD). These geoprocessing models could easily be modified to generate a "Basic Time Series" for any county in California that has FMMP maps;
- *The Detailed Time Series* modifies the "Basic Set" with additional information blended in from Tulare County PARCELS data.

Planned Future Efforts

Subject the TLCCS Time Series to critical peer review:

- The counties participating in the Caltrans Blueprint Project for combining Land Use and Transportation planning in the San Joaquin Valley would benefit from having a consistent time series of Land Cover maps generated by applying their county-specific data to the Geoprocessing models developed by Tulare County GIS. (*The Basic Time Series* of TLCCS maps can be generated for any county in California that has FMMP and DWR maps (certainly every county in the San Joaquin Valley).)
- There are many efforts to develop urban growth simulation models at universities. (The UPlan model from UC-Davis, the SLEUTH model from UC-Santa Barbara, and the UrbanSIM model from the University of Washington to name a few.) A major limitation on the development of such models is the huge effort required to assemble the land use data required to test such models. If Tulare County were to release to certain universities the data set and Geoprocessing models needed to develop the TLCCS time series of maps, it is likely that the TLCCS and models would receive critical review and suggestions for improvement.
- All data and geoprocessing models will be available on the County's GIS FTP site.

Extend the modeling effort:

- By Aug'06, a draft geoprocessing model of development attractors and repulsors will be prepared. (This is information required by the UPlan model. The geoprocessing model captures the assumptions and weights assigned by GIS, and allow county planners (TCAG and County Wide Planning) to explore alternate ways of calculating development attractors and repulsors.)
- By Sept'06, GIS will create an initial draft implementation of the UPlan Model for Tulare County, implementing various scenarios specified by TCAG. GIS will provide technical assistance to TCAG as they explore how different policies might impact future land use patterns, as modeled by UPlan.

- By Oct'06, GIS will develop tools that will allow Transportation Analysis Zones (TAZ) to be refreshed with information from the Time Series, the County Wide Master Plan, and UPlan Scenarios - providing an estimate of the area of specified land uses and the number of dwelling units in each TAZ, for each time period specified by TCAG.
- By Mar'07, GIS will refresh the TLCCS time series with data through 2006, correcting any deficiencies that have been identified through the use of the data (this will be an annual process – perfection is infinite, and we are not).

Land Cover Change (1986 to 2004):

xTLCCSn2	xTLCCSn2	1986d	1988d	1990d	1992d	1994d	1996d	1998d	2000d	2002d	2004d	Change	% change
11	Developed Residential - Rural	14.44	14.44	14.44	14.47	14.47	14.49	14.65	14.67	14.78	14.81	0.37	2.6%
12	Developed Residential - Suburb	26.44	26.61	27.18	28.13	28.30	28.95	31.45	31.91	34.28	35.47	9.03	34.1%
13	Developed Residential - Urban	12.90	13.15	13.49	13.99	14.23	14.99	15.76	16.14	16.91	17.31	4.41	34.2%
14	Developed Commercial	5.78	5.82	5.89	6.02	6.09	6.19	6.43	6.55	6.80	7.00	1.21	20.9%
15	Developed Industrial	6.48	6.67	6.87	7.41	7.56	7.66	8.42	8.72	9.49	9.59	3.11	48.0%
16	Developed Public/Quasi-Public	5.81	5.83	5.89	6.14	6.22	6.34	6.55	6.79	7.35	7.47	1.66	28.6%
17	Developed Open Space	2.47	2.47	2.49	2.51	2.51	2.64	2.75	2.76	2.87	2.90	0.44	17.8%
18	Developed Vacant Land	4.22	4.30	4.37	4.54	4.53	4.63	5.01	5.12	5.56	5.90	1.69	40.1%
19	Developed Transportation	9.58	9.59	9.62	9.62	9.63	9.64	9.76	9.76	9.85	9.86	0.28	2.9%
21	Agriculture Perennial Crops	473.05	473.67	474.62	474.77	478.86	493.69	494.28	495.35	503.71	581.54	108.49	22.9%
22	Agriculture Annual Crops	752.15	751.41	747.00	741.15	751.46	732.04	720.59	707.41	678.26	588.78	(163.37)	-21.7%
23	Agriculture Sheds & Facilities	1.27	1.36	1.43	1.47	1.42	1.42	1.56	1.59	1.75	1.80	0.53	41.7%
24	Agriculture Animal Operations	7.28	8.58	12.93	15.64	15.77	17.39	21.69	24.91	29.34	29.87	22.59	310.2%
31	Water Natural (lakes/ponds/ice)	18.67	18.67	18.67	18.67	18.67	18.67	18.66	18.66	18.66	18.66	(0.01)	0.0%
32	Water Reservoirs	3.78	3.78	3.78	3.78	3.78	3.78	3.78	3.78	3.78	3.78	0.00	0.0%
33	Water Wetlands	63.12	63.12	63.09	63.09	63.10	63.09	63.00	63.00	62.98	62.98	(0.14)	-0.2%
34	Water Systems	19.44	19.44	19.44	19.46	19.45	19.45	19.45	19.44	19.47	19.47	0.03	0.2%
41	Natural Forest Lands	1706.10	1706.03	1706.00	1705.99	1705.77	1705.77	1705.72	1705.74	1705.78	1705.81	(0.29)	0.0%
42	Natural Grass Lands	1533.10	1531.13	1528.86	1529.25	1514.47	1515.49	1516.82	1523.69	1534.44	1542.95	9.85	0.6%
43	Natural Barren Lands	167.72	167.73	167.72	167.73	167.49	167.47	167.45	167.60	167.74	167.83	0.11	0.1%
Total		4833.80	4833.80	4833.80	4833.80	4833.80	4833.80	4833.80	4833.80	4833.80	4833.80	0.00	0.0%

xTLCCSn1	xTLCCSn1	1986d	1988d	1990d	1992d	1994d	1996d	1998d	2000d	2002d	2004d	Change	% change
1	Developed Lands	88.12	88.88	90.25	92.83	93.54	95.53	100.79	102.41	107.89	110.32	22.20	25.2%
2	Agricultural Lands	1233.75	1235.02	1235.98	1233.03	1247.52	1244.55	1238.12	1229.27	1213.04	1202.00	(31.76)	-2.6%
3	Water Lands	105.01	105.01	104.98	104.99	105.00	104.99	104.90	104.89	104.90	104.90	(0.11)	-0.1%
4	Natural Lands	3406.92	3404.89	3402.59	3402.96	3387.73	3388.73	3389.99	3397.24	3407.96	3416.58	9.67	0.3%
Total		4833.80	4833.80	4833.80	4833.80	4833.80	4833.80	4833.80	4833.80	4833.80	4833.80	0.00	0.0%

The TLCCS creates a three digit number of seventy-seven (77) different land cover codes that the system monitors. This is too many distinctions to understand. If you divide each land cover code by ten, the result is twenty (20) categories. If you divide each of these land cover code by ten, the result is four (4) basic categories – developed lands, agricultural lands, water lands, and natural lands.

In the eighteen years that the TLCCS monitors, the county has gained 22.59 square miles of confined animal corals (TLCCSn2 = 24), which is larger than the increase of all urbanized lands (TLCCSn1 = 1).
Over this period, greatest land cover loss has been 167.37 square miles of field crops; the greatest land cover gain has been 108.49 square miles of perennial crops (orchards and vineyards). In the eighteen years that TLCCS monitors, there has been a net loss of 31.76 sq. miles of Agriculture (TLCCSn1 = 2) and net gains of 22.20 sq. miles of developed/urbanized lands (TLCCSn1 = 1) AND 9.67 sq. miles of natural lands (TLCCSn1 = 4). Most of this increase in 'natural lands' is a product of the US Bureau of Land Management's program to acquire marginal farmland in the

area south of Alpaugh in order to restore natural habitat and to reduce the Federal Government's obligations to provide irrigation water to that area.

Testing TLCCS Data:

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
nTLCCS3	nTLCCS3	1988d	1989d		1990d	1992d	1994d	1996d	1998d		2000d	2002d	2004d		Change	% change
	Check #1 - Bovine CAFO Area -vs- Bovine Population															
		1988d	1989d		1990d	1992d	1994d	1996d	1998d		2000d	2002d	2004d		Change	% change
242	Bovine Feedlots	1.06	1.12		1.34	1.69	1.75	1.87	2.31		2.49	3.14	3.16		2.10	198.03%
243	Bovine Dairies	5.65	6.60		10.31	12.53	12.79	14.27	17.95		20.98	24.67	25.18		19.53	345.69%
	Bovine Area (sq.mi. of corral	**6.71**	**7.72**		**11.64**	**14.22**	**14.53**	**16.14**	**20.26**		**23.48**	**27.81**	**28.33**		**21.63**	
	Bovine AUs - GIS Dairy Study (2005)				273650	321350	325561	358410	446177		512349	601800	610250			
	AU/sq.mi.				23500.5	22595.6	22402.9	22219.2	22017.5		21924.8	21637.2	21537.4			
	density change				0.00%	96.15%	95.33%	94.51%	93.69%		92.87%	92.07%	91.65%			
	Check #2 - dwelling unit estimate -vs- US Census															
					1990d	1990-DU					2000d	2000-DU			Change	% change
		DU/acre	DU/sqmi		sq.mi.											
111	Rural Farmsteads	0.40	256.0		13.656	3496					13.656	3496			0.000	0.00%
112	Rural Homestead	0.10	64.0		0.603	39					0.786	50			0.183	30.37%
113	Rural Mtn Cabin (seasonal)	0.00	0.0		0.009	0					0.012	0			0.003	29.63%
115	Rural Campsites	0.00	0.0		0.174	0					0.212	0			0.037	21.31%
121	Res: Extremely Low Density	0.30	192.0		5.939	1140					7.534	1446			1.595	26.85%
122	Res: Very Low Density	0.80	512.0		6.668	3414					8.129	4162			1.461	21.91%
123	Res: Low Density	1.55	992.0		3.408	3380					3.804	3773			0.396	11.63%
124	Res: Low/Moderate Density	3.10	1984.0		11.166	22154					12.448	24697			1.282	11.48%
131	Res: Moderate Density	6.50	4160.0		10.113	42056					12.435	51730			2.325	23.00%
132	Res: Moderate/High Density	12.50	8000.0		2.898	23187					3.198	25581			0.299	10.32%
133	Res: High Density	17.00	10880.0		0.485	5274					0.504	5478			0.019	3.87%
	Total Residential Area (sq.mi.)				55.12						62.72				7.600	13.79%
	Total DU (GIS estimate)					104142						**120413**			16273	15.63%
	DU / res sq.mi.					1889.49						1919.99				
	Urban Residential Area (sq.mi.)				40.67						48.05				7.377	18.14%
	Urban DU (GIS estimate)					100608						116867			16261	16.16%
	DU / res sq.mi.					2473.51						2432.19				
	Total DU (US Census)					**105013**						**119639**				
	Census - DU (occupied)					**97861**						**118865**				
	Census - DU (vacant)					**7152**						**9254**				
	Error #					(873)						**774**				
	Error %					-0.83%						0.65%				

Reality Check #1: From previous work, GIS had estimates of the number of 1400 pound bovine animal units in the County in 1990, 1992, 2002, and 2004. These numbers were compared with the area of confined bovine animal operations for those years. The result is that the density of bovine animals within corals has slightly declined since 1990. Since environmental constraints have been increasing, this result seems credible.

Reality Check #2: The TLCCS records residential lands by dwelling unit density. The number of dwelling units in the county in 1990 and 2000 was estimated areas of residential lands of different densities. These estimates were compared to the number of dwelling units reported by the US Census… The GIS estimate had an error of less than 1%.