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Abstract

In the next 40 years, the eight counties of the San Joaquin Valley are projected to double in population from 3.3 million to more than 7 million (Great Valley Center 2006). The region faces many challenges with respect to its capacity to accommodate this dramatic increase in population while maintaining its environmental infrastructure and preserving its diminishing natural resources.

In response to these growing pressures, Governor Schwarzenegger announced in June 2005 the formation of the California Partnership for the San Joaquin Valley (Partnership) to "the economic well-being of the Valley and the quality of life of its residents" (Department of Business Housing and Transportation 2006a). This 26-member Partnership, led by the Secretary of the Business, Transportation and Housing Agency, is composed of eight state government members (primarily cabinet level appointees), eight local government members (primarily members of county boards of supervisor), eight private sector members (representing leadership in various business sectors), and two deputy chairs. The Partnership region includes San Joaquin, Stanislaus, Merced, Madera, Fresno, Tulare, Kings, and Kern Counties.

The Information Center for the Environment (ICE) at UC Davis supported the Partnership by providing geographic information system (GIS) data and growth allocation build-out scenarios. Based on input from the Partnership and the Great Valley Center, ICE developed and produced seven urban growth scenarios for the region that project popula¬tion to year 2050 using UPlan, a rule-based GIS urban growth model (Johnston et al. 2006). These scenarios were developed based on different goals (such as Compact—within current spheres of influence; Farmland Protection—prime farmland masked; Great Cities—create "mega-cities" in concentrated regions) and produced vastly different outcomes.

This paper discusses the seven growth scenarios and the implications of mapped future urban growth in the San Joaquin under those scenarios on a collection of biologically significant factors. A team of federal, state, and non-government organization biological experts selected 14 key biological layers crucial for protecting high value open space in the San Joaquin Valley. ICE combined the modeled urban growth output for the seven growth scenarios with the 14 biologically significant GIS layers. The growth scenarios reflect seven different policy directions that the region's leaders may choose when planning for growth in the upcoming several decades. Results showed that depending on the scenario

chosen (and hence the policy emphasis), the magnitude of biological resources likely to be lost varies significantly. The scenario with the least overall ecological impact is the Compact Growth Scenario (Scenario 3), with Scenarios 6 (New Cities) and 7 (Great Cities) also fairly low in relative impact. Scenario 4 (Prime Farmland Protection) resulted in the largest decline in the acreage of the 14 key biological data layers we examined. Scenarios 5 (I-5 to Highway 99 Exclusion), 2 (East/West Road Improvement) and 1 (Status Quo) also showed relatively high negative impacts.

IMPACTS OF DIFFERENT GROWTH SCENARIOS IN THE SAN JOAQUIN VALLEY OF CALIFORNIA

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Introduction

The growth of human populations inevitably has an effect on the natural environment. As human populations continue to increase, so do the conflicts for land use. As urban areas expand, vital natural resources diminish. Once lost, most of these resources cannot be recovered. Over the long term, the cumulative impact of environmental degradation negatively affects human health and well-being. One way to minimize anthropogenic impacts on the environment is through scientific inquiry and informed planning.

In the United States, the planning process occurs at the local level. Although most laws and regulations, such as environmental protection (CEQA—California Environmental Quality Act) and source water protection laws (Clean Water Act, Safe Drinking Water Act), are made at State and Federal levels, local planning happens on Tuesday nights at City Council and County Board of Supervisor meetings scattered throughout 478 cities and 58 counties across California (Fulton and Shigley 2005). All too often, the results of this system are inconsistent planning across jurisdictional boundaries and lack of regionally coordinated efforts. The cumulative effects of multi-jurisdictional decisions are rarely considered in any one decision. Conceptualizing the effects of individual decisions on regional resources is difficult without the aid of analytical tools seldom available to local decision makers.

One approach to quantifying the magnitude and nature of the impacts of population growth on existing regional resources is to use an urban growth model implemented in a geographic information system (GIS) to assess the ecological impacts of the projected future growth. One example of this approach involved four growth scenarios developed for the San Joaquin Valley using a cellular automata model called SLEUTH (Teitz 2005) to model growth distributions. Another example is the Partnership in Integrated Planning Process implemented in Merced County, California (Smith et al. 2004) where the community interacted with modelers to create scenarios that reflected the community's perceived range of options.

Our approach was to use UPlan, an urban growth allocation model developed by Professor Robert Johnston and others at UC Davis (Johnston, Lehmer et al. 2006). UPlan has been used for several growth modeling projects, including the Partnership in Integrated Planning process in Merced County (Smith, Scherzinger et al. 2004) and, more recently, the San Joaquin Valley Blueprint process (The Great Valley Center 2006). We also chose to use a process of "community" participation in building the model by having Partnership subcommittee members take part in the creation of the scenarios to be modeled.

From a policy perspective, the Partnership for the San Joaquin Valley provides an excellent example of trying to solve a collective action problem through coordinated local planning. The members of the Partnership come from local city councils and boards of supervisors from the eight counties; they are *local* decision makers. Rather than the typical case of individual cities and counties planning land use policy independently, this group coordinated and developed consensus through a series of meetings and produced joint recommendations for the region. Because the Partnership was initiated by an executive order, the State has also played a key role. As a result of the Partnership's efforts, California has allocated 2.5 million dollars in seed money for the first year for projects aimed at fulfilling the Partnership's recommendations (Department of Business Housing and Transportation 2006b).

Study Area

The San Joaquin Valley of California (figure 1) includes eight counties and occupies about 17.5 million acres of land (approximately 27,500 square miles). It is a geographically and biologically diverse region with rich natural resources. During pre-European settlement times, the valley floor was well connected to the foothills and mountains through natural community linkages, and thus constituted a healthy, functioning ecosystem (Meade and McCoy 2006). During the late nineteenth and early twentieth centuries, the San Joaquin Valley became one of the most productive agricultural centers in the country. For many decades it was known strictly as an agricultural center, but as housing and population pressures in the coastal regions of California have increased, the population of the San Joaquin Valley region has started to increase and the pressures on its resources have intensified. In the next 35 to 40 years, the population of the San Joaquin Valley is expected to more than double, increasing from 3.3 million in 2000 to more than 7 million by 2040 (Teitz 2005), and by 2050 there are likely to be close to 8 million San Joaquin Valley residents (Department of Finance 2004b).

This region, which is currently growing faster than Mexico (Central Intelligence Agency 2002) and has a poverty rate higher than Appalachia (Rural Migration News 2006), will need to accommodate this predicted growth, while preserving and expanding its economic base. Some interesting statistics about the region in comparison to the rest of the state of California include the following (Department of Business Housing and Transportation 2006b):

- Average per capita incomes are 32.2% lower than the rest of California.
- College attendance is 50% below the state average.
- Violent crime is 24% higher.
- Access to healthcare is 31% lower.
- Air quality is among the worst in the nation.

The need to accommodate growth, stimulate the economy, and protect the environment of the San Joaquin Valley help make this a region of vast importance to the State of California and to the rest of the nation. Individual jurisdictional priorities must give way to effective regional collective action. The use of forecasting tools provides a powerful methodology for stimulating such collective action.

Figure 1. The San Joaquin Valley of California includes eight counties in the southern part of the Central Valley. The thick outline represents the 2500' boundary used by the San Joaquin Valley Partnership's Land Use, Housing and Agriculture (LUHA) Work Group for data layers. The same boundary was used for all analyses described in this paper.

Methods

The UPlan Model

In early 2006, the Partnership's Land Use, Housing and Agriculture Work Group (LUHA) requested that ICE implement several potential growth scenarios based on different growth policies defined by LUHA. The parameters associated with each scenario were developed in a collaborative process during several LUHA meetings at the Great Valley Center in Modesto. ICE implemented these scenarios using the GIS-based urban growth model, UPlan, that Robert Johnston created several years earlier (Information Center for the Environment 2006) and that ICE recently enhanced.

UPlan projects spatially explicit urban growth patterns in several land categories. Four residential, one industrial, and two commercial densities are represented. The model does not calibrate based on historical data because its intended use is for long-range scenario testing. It relies on fine-grained raster data (the cell size may be determined by the user) that represent existing urban, local general land use plans, and all other relevant natural and built features that define the model. It is deterministic and rule-based, so as to be transparent to the user. The urban growth allocation rules broadly simulate land markets. The model is free to the public and can be applied to counties, metropolitan regions, watersheds, and bioregions. UPlan allocates growth to different cells using attractors that encourage growth and discouragements that discourage growth.

Some assumptions of UPlan are the following:

- Population growth can be converted into demand for land use by applying conversion factors to employment and households.
- New urban expansion will conform to real or hypothetical city and county general plans.
- Cells have different attraction weights because of accessibility to transportation and infrastructure.
- Some cells, such as lakes and streams, will not be developed. Other cells, such as sensitive habitats and floodplains, can be weighted to discourage new development.

UPlan is easy to use and informative for planners and citizen groups alike (Johnston, Lehmer et al. 2006). UPlan users can change the assumed growth rates or other basic assumptions and can set various environmental and social attractors and discouragements to growth such as the built environment, sensitive habitat, or agricultural lands (Smith, Scherzinger et al. 2004). UPlan has been used for several applications during the past few years, including modeling urban buildout along California's highways (Thorne et al. 2006), transportation planning (Johnston et al. 2003), and modeling future development in California's Sonoma County (Merenlender et al. 2005).

For all seven LUHA growth scenarios, we applied the following set of parameters:

Growth Attractors:

- US Census Blocks with Growth 1990-2000
- Major Arterials
- Minor Arterials
- Highways (not using ramps)
- Freeway Ramps
- Spheres of Influence

Growth Discouragements:

- The Nature Conservancy Priority Conservation Areas
- Vernal Pools (Holland)
- FEMA Q3 Floodplains
- California Natural Diversity Database records

Areas Masked from New Growth:

- Existing Urban (Derived from Department of Conservation's Farmland Mapping and Monitoring Program)
- Streams 100m buffer
- Lakes 100m buffer
- Public Land

Where additional Attractors, Discouragements, or Masks were applied, these are indicated in the specific scenario descriptions in the next section. The growth projection numbers used for all scenarios in the model came from the Department of Finance for the year 2050 (Department of Finance 2004a). Inputs were derived from easily accessible and publicly recognized data sources such as the US Census, California Department of Finance, California Department of Conservation, California Department of Transportation, California Resources Agency and University of California, Davis spatial and demographic data libraries.

UPlan Scenarios

We used UPlan to analyze the potential effects of seven different urban growth scenarios on 14 key biological data layers. The following provides a description of the basic goals of each scenario, as described in the ICE metadata for the output GIS layers for each scenario run.

1. **Status Quo Scenario**—Industry, Commercial High, Commercial Low, Residential High and Residential Medium were allowed to go into agriculture if all growth could not be allocated within the current general plans. Residential Low and Residential Very Low were also allowed to go into agriculture if all growth could not be allocated within the current general plans. This model run showed a possible outcome if no significant changes are made to urban growth policies through 2050. This run was used to provide a baseline against which other models can be compared.
2. **East/West Road Improvement Scenario**—Inputs and allocation rules were the same as Scenario 1 except the East/West roads of interest (I-580, 205, Highway 4, 12, 58, 140, 152) were given double weight as hypothetical highway capacity enhancements resulted in increased accessibilities that were attractors to growth. The East/West Road Improvement model run showed a possible outcome if growth is encouraged along seven existing major East/West roads. This run modeled a policy of improving the infrastructure along these already-existing highways.
3. **Compact Growth Scenario**—Inputs were the same as Scenario 1 except Residential Low (RL) and Residential Very Low (RVL) were eliminated and their population was added to Residential Medium (RM). All growth was allocated within current Spheres Of Influence (SOI). If the needed growth was under-allocated then RM housing density was increased to accommodate the growth within existing SOI's. Increased density was necessary in all counties except Kings. In some cases the development could not be sustained entirely in the RM category without dropping RM below 0.1 acre per dwelling unit. When this occurred the development pattern was shifted to 33% RH and 67% RM. These changes were needed in San Joaquin, Merced and Stanislaus counties. This run modeled a policy of very compact growth where increased population is accommodated by increasing densities rather than modifying boundaries and building outside the existing SOIs.
4. **Farmland Protection Scenario**—Prime farmland and farmland of statewide importance were used as a mask. All other variables were the same as Scenario 1. In Fresno County, Commercial Low (CL) and RM were allowed to go into RL, RVL and agricultural land. This run modeled a policy of protecting particularly high-valued farmland as a top priority and required all growth to be allocated outside of these designated areas.
5. **I-5 to Highway 99 Exclusion Scenario**—The area between I-5 and Highway 99 was used as a mask. All other variables were the same as Scenario 1. This run modeled a policy of restricting all new growth to occur to the west of I-5 and to the east of Highway 99. Such a policy would protect a great deal of existing prime farmland and would encourage growth on either side of these major roadways (but not between them).
6. **New Cities Scenario**—Four new cities with populations of approximately 250,000 were created in areas of relatively low agricultural and environmental importance near significant entry points from the California Coast to the SJV. Residential densities were increased by 15% for all classes except RVL (which was eliminated). Population from the RVL class was added to the RL class resulting in a net increase in RL area occupied despite the increased density. This run modeled a policy of creating new cities in areas that do not have high farmland or biological value. Such a policy would focus growth in compact areas by creating four new urban centers.
7. **Great Cities Scenario**—Existing major cities were encouraged to grow to house the predicted population growth. Residential densities were increased by 15% for all classes except RVL (which was eliminated). Population from the RVL class was added to the RL class resulting in a net increase in RL area occupied despite the increased density. This run modeled a policy of creating two or three new "megalopolis" areas of over one million inhabitants. Such a policy would promote growth immediately surrounding existing larger urban centers.

We ran the UPlan model for each of the seven scenarios. The different outcomes of each scenario reflected different potential growth policies. Results from each Uplan model run were in raster format by county. These were merged into one regional layer (all eight counties) for each run and were converted back to a vector layer.

Biological Conservation Priority Layers

ICE used a series of GIS data layers to develop the set of conservation opportunity areas for the California Partnership's LUHA Work Group. These areas featured concentrations of priority conservation targets as identified by a group of natural resource professionals during the planning process. The areas were meant to help focus conservation efforts towards those locations that are most critical to the future ecological well-being of the region.

The first step in the process of the ecological data set creation was to hold a series of meetings involving a wide range of natural resource planners representing federal, state, local, and private agencies and organizations. These attendees identified fourteen key biological conservation priority layers in the SJV (Meade and McCoy 2006). The source for each layer is indicated in parenthesis following the layer name.

- Desert scrub (CA GAP Analysis Project)
- Blue oak woodland (CA GAP Analysis Project)
- Sensitive ecological communities (CA Natural Diversity Database)
- Grasslands Ecological Area (Central Valley Habitat Joint Venture)
- Historic lakebeds (Endangered Species Recovery Program)
- Kit fox habitat (intersection of CA Natural Diversity Database kit fox locations with Endangered Species Recovery Program annual grassland and desert scrub polygons)
- Buffers around existing conservation areas (Public/Conservation Trust Lands buffered 2 km)
- 100-year floodplain (FEMA Q3 flood data)
- Riparian corridors (500 m buffers around named rivers from National Hydrography Dataset)
- Perennial grassland (CA GAP Analysis Project)
- Tehachapi corridor (Endangered Species Recovery Program natural land cover polygons between I-5 and Hwy 58)
- High concentrations of sensitive species (CA Natural Diversity Database—A compiled density of threatened and endangered species built around 2000-meter wide hexagonal cells. The dataset was created by generating a blank hexagon grid, intersecting it with the May 2005 CNDDB dataset, and then counting the number if unique species from the CNDDB within each hexagon cell. All hexagons with at least four sensitive species occurrences were used in the analysis)
- Vernal pool complexes in Stanislaus, Merced, Madera, and Fresno Counties (U.S. Fish and Wildlife Service)
- Tulare Basin planning areas (Tulare Basin Wildlife Partners)

These conservation priority factors were obtained in or converted into GIS layers. The map extent used for these layers, shown in figure 1, included all areas in the eight San Joaquin Valley counties up to 2,500 feet in elevation (for a total of 16,736 square miles). This analysis does not include data beyond this boundary.

Combining UPlan Scenario Outputs with Biological Conservation Priority Layers

The final step was to combine the output from the seven growth scenarios with the fourteen biological conservation layers. We overlaid each of the seven region-wide scenario outputs with each of the fourteen conservation priority layers developed by ICE (Meade and McCoy 2006) using ESRI's ArcEditor version 9.2 (Environmental Systems Research Institute). We also calculated and summarized the total acreage of each resource that would be converted to human use (including residential, industrial, and commercial uses) given the different growth scenario outcomes. The goal of this analysis was to identify which scenarios, if implemented, would have the least negative impact on these resources in the SJV.

Results

Depending on the scenario chosen (and hence the policy emphasis), the number of acres of biological resources likely to be lost due to growth varied significantly. The results of this analysis are shown in table 2. The scenario with the overall least amount of impact was the Compact Growth Scenario (Scenario 3), with Scenarios 6 (New Cities) and 7 (Great Cities) also fairly low in relative impact. Scenarios 1 (Status Quo) and 2 (East/West Road Improvement) showed higher overall environmental consequences, while Scenarios 4 (Prime Farmland Protection) and 5 (Between I-5 and Highway 99 Exclusion) resulted in the largest decline in the acreage of the fourteen biological resources data layers we examined.

Another important way to look at the data is to calculate the percent of each biological resource that would be impacted by each modeled scenario (rather than looking at the number of acres of impact). Table 2 presents the results of this calculation. Of particular note are those cases where over 10% of the resource would be lost. This situation occurred for vernal pools in both the Scenario 4 (Farmland Protection - 14.28%) and Scenario 5 (Between Highway Exclusion - 11.53%) model runs. Also, Scenario 2 (East/West Road Improvement) resulted in a 13.72% loss of the region's perennial grasslands, and Scenario 4 (Prime Farmland Protection) was projected to eliminate over 14.5% of the region's blue oak woodlands. Scenario 3 (Compact Growth), on the other hand, would not impact any of the blue oak woodlands, and would result in a less than 2% reduction of each of the other biological factors except for perennial grasslands (4.38%). The results are quite dramatic when one considers the importance of these biological resources to the overall health of the regional ecosystem.

Table 1: Impacts of seven UPlan growth scenarios on selected biological resources (in acres). The number of acres impacted by each Scenario is shown for each of the 14 biological factors. The lowest impact for each resource is shown in Italics, while the highest is shown in Bold

	Scenarios						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Conservation Buffers	197,313	198,239	*52,007*	**252,035**	240,252	96,665	89,737
CNDDB High Density	52,807	52,087	*21,699*	**74,803**	57,469	24,593	22,886
Desert Habitat	10,666	11,179	*1,260*	**15,595**	10,540	2,578	2,925
FloodPlain	110,112	**110,906**	*15,698*	98,741	107,586	51,792	90,364
Grasslands	6,726	7,551	332	13,585	*0*	1,674	28
Kit Fox	39,648	40,267	*8,002*	**92,006**	56,507	9,148	8,732
Lakes	**9,382**	9,199	141	6,837	1,490	1,054	*88*
Blue Oak Woodland	14,162	14,037	*0*	**85,963**	32,473	776	47
Perennial Grasslands	692	1,188	379	699	*4*	428	575
Riparian	19,988	20,272	*2,859*	21,115	**22,970**	10,150	13,787
Sensitive Communities	9,385	9,754	*622*	**21,866**	6,210	1,363	2,850
Tulare Basin	29,559	28,693	*161*	**41,951**	7,705	1,270	413
Tehachapi	1,146	1,113	*0*	**1,551**	1,469	*0*	*0*
Vernal Pools	16,682	15,960	2,036	**43,345**	34,980	*668*	1,899

Table 2: Percent of total amount of biological resource impacted by predicted growth allocations in each scenario

	Scenarios						
Biological Factors	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Conservation Buffers	**6.61%**	**6.64%**	**1.74%**	**8.44%**	**8.05%**	**3.24%**	**3.01%**
CNDDB High Density	**5.68%**	**5.61%**	**2.34%**	**8.05%**	**6.19%**	**2.65%**	**2.46%**
Desert Habitat	**2.59%**	**2.72%**	**0.31%**	**3.79%**	**2.56%**	**0.63%**	**0.71%**
Flood Plains	**6.46%**	**6.50%**	**0.92%**	**5.79%**	**6.31%**	**3.04%**	**5.30%**
Grasslands	**3.64%**	**4.08%**	**0.18%**	**7.34%**	**0.00%**	**0.90%**	**0.02%**
Kit Fox	**3.27%**	**3.33%**	**0.66%**	**7.60%**	**4.67%**	**0.76%**	**0.72%**
Lakes	**3.57%**	**3.50%**	**0.05%**	**2.60%**	**0.57%**	**0.40%**	**0.03%**
Blue Oak Woodland	**2.39%**	**2.37%**	**0.00%**	**14.51%**	**5.48%**	**0.13%**	**0.01%**
Perennial Grasslands	**7.99%**	**13.72%**	**4.38%**	**8.08%**	**0.04%**	**4.95%**	**6.65%**
Riparian	**5.05%**	**5.13%**	**0.72%**	**5.34%**	**5.81%**	**2.57%**	**3.49%**
Sensitive Communities	**4.18%**	**4.35%**	**0.28%**	**9.74%**	**2.77%**	**0.61%**	**1.27%**
Tulare Basin	**4.97%**	**4.82%**	**0.03%**	**7.05%**	**1.29%**	**0.21%**	**0.07%**
Tehachapi	**1.75%**	**1.70%**	**0.00%**	**2.36%**	**2.24%**	**0.00%**	**0.00%**
Vernal Pools	**5.50%**	**5.26%**	**0.67%**	**14.28%**	**11.53%**	**0.22%**	**0.63%**

Discussion

The results of this analysis indicate that Scenario 3 (Compact Growth) is the best strategy for minimizing the overall effect on biological resources while accommodating growth during the coming four decades. We are not suggesting that the Compact Scenario be adopted as is without other factors considered. We do recommend accommodation of a large portion of projected growth in high density residential areas that remain, as much as possible, within the footprint of existing towns and cities. We recommend encouraging growth immediately adjacent to and within existing large urban areas and creating “Great Cities” (Scenario 7) and/or considering the development of new cities (Scenario 6) rather than permitting urban and exurban sprawl. These three strategies provide for the projected growth and result in less impact to the region’s precious biological resources.

Conclusion

This paper provides guidance for planners held responsible for the future footprint of human settlement in the region. The San Joaquin Valley of California is one of the fastest growing regions in the country. With staggering projected growth rates for the region, intelligent planning is essential if limited, valuable resources are to be preserved for future generations. The methods presented here may also become a useful template for examining possible outcomes of growth strategies and assessing regional planning in other parts of the state.

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Michael C. McCoy serves as academic administrator and principal investigator for the Information Center for the Environment. He specializes in the development, aggregation and dissemination of environmental information. In this capacity he works with a variety of agencies, committees and funding sources and works to achieve consensus on the best strategies for integrating data and implementing strategy. Projects include studies of regional environmental planning methodologies, land use and infrastructure planning policy, and the development of rule based and microeconomic land use models.

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