Smarter Land-Use Analysis:

The Land-Use Conflict Identification Strategy Model™

Of Christian County, Missouri

Research Synopsis
Prepared by:
David Faucett

Abstract

Land-use suitability analysis is one of the most useful applications of GIS for planners and land managers. The goal of this type of analysis is to identify the most suitable land use pattern based on specific criteria or preferences. Contemporary GIS has developed along a similar trajectory with a planning approach towards collective design. GIS has become a potent component of Planning Support Systems (PSS) that seek to integrate empirical "geodata" with normative social values. The Land Use Conflict Identification Strategy (LUCIS™) model integrates these concepts and can be of high value in certain jurisdictions that seek to incorporate traditional zoning schemes on the heels of rapid growth. Christian County, Missouri has been the fastest growing county in the state over the past two decades. Growth in some parts of the county has outpaced the capacity of the transportation network and has led to transportation issues becoming one of the highest priorities in terms of new development. Multi-criteria accessibility measures, based on an ad hoc residential location preference survey, were incorporated as part of the LUCIS™ model to aid in decision support for a major thoroughfare plan that accommodates future growth in conjunction with a future land use map.

Introduction

Land-use planning remains one of the most powerful tools of planners. Zoning schemes are the result of a spatial logic that manifests itself into a functional mosaic of prescribed intensities of various human activities across the landscape that promotes the health, safety and general welfare of the public at large. Growing environmental awareness and a Malthusian-like epiphany in terms of the exhaustion of non-renewable resources in the latter half of the twentieth century have culminated in the emergence of sustainable development as the controlling paradigm of community and regional planning. Today land-use planning has become entrenched in a complex and dynamic struggle to discern the most efficient spatial organization of human endeavor that balances environmental quality and resource constraints against economic development in an equitable manner for all members of the community and future generations. This "triple bottom line" of sustainable development is a difficult construct to allow fomenting completely in one's mind and an even trickier ideal to implement in reality. A reality that is dominated by socio-political fragmentation and conflicting values between special interests seeking to advance one component over another. Yet sustainable development can be a unifying concept that brings together many different concerns under one overarching goal that reflects a set of social priorities and articulates how society values the economy, the environment and equity (Campbell, 1996).

Approaching sustainable development in terms of land-use management presents the paradox concerning two seemingly contradictory objectives of nature conservation and economic growth. The need to reconcile these conflicting objectives has fostered a planning arena that provides a seat at the table for representatives of dissonant perspectives in order to reach a moral consensus regarding a set of proposed alternatives to an optimal pattern of land-use. Land-use suitability assessment has become an invaluable process for decision makers involved in urban and regional land-use planning. Land-use suitability assessment is a map overlay technique or the process of combining geo-

graphically varying attributes describing the optimal suitability or capacity land to support a specified land-use type. This technique emanates from the field of landscape architecture and an ecological perspective advanced by the work of Ian McHarg.

Ian McHarg, considered the father of an ecological planning perspective, developed a comparative map overlay methodology that has "popularized and advanced the application of multiple 'cake layers' for incorporating the environment and social constraints into the myopic developers dreams of paving the planet" (Foresman, 1998). McHarg (1969) presented this method in his quintessential work *Design with Nature*, "let us map physiographic factors so that the darker the tone the greater the cost. Let us similarly map social values so that the darker the tone, the higher the value…make the maps transparent, superimpose them over a light table and scrutinize them for their conclusion." It was McHarg's intent to counter the pervasive and, in his view, environmentally degrading hard data of cost-benefit analysis and economic determinism with value driven soft data of an ecological perspective in the spatial decision making process. This innovative methodology was the precursor to the advancement of land-use suitability assessment techniques that have become synonymous with McHarg's name and have influenced the computer language and methodology developed as part of all current GIS programs (Palmer, 2001; Malcweski, 2004; Davis et al, 2002). In this context, reducing the role of the techno-positivist and increasing the value of collective goals, "GIS is seen as a tool for plan-making *with* the public rather than *for* the public" (Malczewski, 2004).

GIS and Multi-Criteria Decision Analysis (MCDA)

MCDA provides a rich set of techniques and procedures for structuring and prioritizing decision problems (Malczewski, 2006). MCDA is a Decision Support technique by which criteria pertaining to choosing the best alternative are defined by experts in conjunction with stakeholders and policy makers through a structured hierarchy of goals and

objectives (Hill et al., 2005). These methods convert subjective qualitative ordinal preference ranks into a quantitative interval/ratio weight that can be used as mathematical operators in multiplication procedures. The attributes associated with each criterion are classified according to their level of measurement to a common scale or ranking of suitability. Subsequently, decision makers rank these criteria as to their relative importance in terms of optimal suitability pertaining to a specified objective. The criteria are then weighted according to rank, and then the attributes associated with each candidate are combined most commonly in an additive weighted linear combination to reveal the best-suited alternative relative to all other candidates.

Statement of Purpose

The purpose of this study is to integrate a multi-criteria analysis of accessibility developed by Zhu et al. (2006) for housing in Singapore into the LUCIS™ model as an explanatory variable describing the demand for growth in residential land-use types based on location-based accessibility to a variety of activities. This methodology will demonstrate an avenue for incorporating community values into the modeling process by utilizing findings from an ad hoc residential location preference questionnaire and explore public participation in GIS (PPGIS). The introduction of GIS-based network analysis into the LUCIS™ model will better describe how accessibility shapes land-use by simulating the market demand for new development based on the recognized relationship between land value and the cost of travel along the transportation network. The ultimate aim of this study is to aid land-use planners and decision makers in formulating future land-use patterns that accommodate both nature conservation and economic growth through the cartographic visualization of the relationship between transportation and land-use that has historically been a contributing factor to low-density suburban development. The methods described above were employed in a case study for Christian County, Missouri.

Methodology

Margaret Carr and Paul Zwick (2007) developed The Land-Use Conflict Identification Strategy (LUCIS™) model over a ten-year period instructing students in a joint studio called the Ecological Design Practicum in the Department of Urban and Regional Planning at the University of Florida. LUCIS™ is a goal driven model that attempts to derive probable future land-use patterns based on the three broad land-use categories of agriculture, conservation and urban. The power of LUCIS™ is touted to "come from the application of its results to develop alternative land-use futures based on community preference and conflict" (Carr and Zwick, 2007). The model is a five-step process of employing traditional land-use suitability analysis to divide regions into subcategories where the three land-use types already exist, where they are preferred and ultimately, where they come into conflict.

Table 7.1 The Five Steps of the LUCIS™ Modeling Process

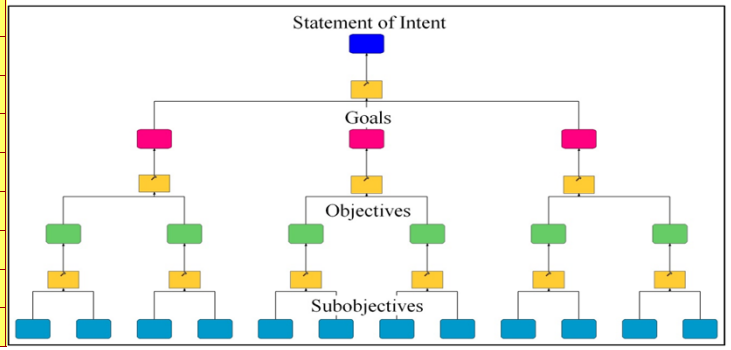
Step	Description
Goals and Objectives	Define goals and objectives that become criteria for suitability
Data Inventory	Identify sources potentially relevant to each goal and objective
Suitability	Analyze data to determine relative suitability of each goal
Preference	Combine relative suitability's of each goal for the three major land-use categories
Conflict	Compare the three land-use preferences to determine likely areas of future land-use conflict

Defining Goals and Objectives

Table 7.2 Structured Hierarchy of Goals and Objectives for Christian County, Missouri Urban Land-Use

Overall statement of intent:	Determine the lands preferred for agriculture, conservation and urban use in Christian County, Missouri. Compare the resulting preferences to derive the most likely locations for future conflict and provide decision support for preferred future land-use pattern.
Urban Land Use	
Statement of intent:	Identify lands most suitable for urban development
Goal 1	Identify land most suitable for residential use
Objective 1.1	Determine land suitably located for residential use
Subobjective 1.1.1	Identify land with high accessibility to employment opportunities
Subobjective 1.1.2	Identify land with high accessibility to healthcare facilities
Subobjective 1.1.3	Identify land with high accessibility to parks and recreation
Subobjective 1.1.4	Identify land with high accessibility to schools and daycare
Subobjective 1.1.5	Identify land with high accessibility to shopping
Subobjective 1.1.6	Identify land proximal to emergency services
Subobjective 1.1.7	Identify land proximal to existing public water and sewer services
Objective 1.2	Determine land physically suitable for residential use
Subobjective 1.2.1	Identify soils suitable for septic systems
Subobjective 1.2.2	Identify soils suitable for roads and streets
Subobjective 1.2.3	Identify soils suitable for structures with basements
Objective 1.3	Determine land with property values suitable for residential development
Goal 2	Determine land most suitable for commercial use
Objective 2.1	Identify land suitably located for commercial use
Objective 2.2	Identify land with soils suitable for small commercial buildings
Goal 3	Determine land physically suitable for urban use
Objective 3.1	Identify land with slopes suitable for development

The development of goals and objectives is a critical first step in the modeling process. This structured hierarchy is designed to provide valuable direction in identifying relevant data for model development. The more time spent in this first step of the process will lead to a more focused design of the model. This structured hierarchy is then used as the base criteria in the next step of identifying relevant data sets to be used as input map layers in subsequent steps. The goals and objectives are not meant to be fixed throughout the process and can be altered during the step of data inventory and preparation. If no direct data exists relevant to the realization of stated goals and objectives indirect contributors or proxy variables must be identified.



LUCIS™ Model Data Inventory (Sources and Layers)

USDA Soil Database and Soil Data Viewer:

Soils Suitability Data:

Prime Farmland [PrmFrm]

Non-Irrigated Crop Yield Index [Yield]

Seedling Mortality Rate [SdlgMort]

Camp Areas [CmpArea]

Picnic Areas [PncArea]

Playground Areas [PlayArea]

Paths and Trails [PthTr]

Small Commercial Buildings [ComBldg]

Local Roads and Streets [RdsStrs]

Dwellings with Basements [DWB]

On-Site Waste Water Absorption Fields [Septic]

Missouri Spatial Data Information Service:

USGS Land Use/Land Cover 2005:

Cropland Class [Crplulc]

Grassland Class [Grsslulc]

Wetland Classes [Wetlnds]

Urban Classes

USGS Digital Elevation Model:

Slope [slope]

Missouri Department of Conservation: [MoDepCon]

Busiek

Delaware Town Access

Shelvin Rock Access

National Forest [NF]

Sinkhole Area Polygons [Snkhle]

Public Schools [PS]

Private Schools [PRS]

Christian County Database:

Golf Course [PrkRec]

Country Club [PrkRec]

Parcel Value Per Acre [PrcVal]

Large Parcels (> or = to 50 Acres) [AgPrc]

City Parks [PrkRec]

Fire Station [FD]

Ambulance District Facilities [AMB]

Wilson's Creek National Battlefield [WCNB]

Floodplain [FP]

City Boundaries

Township and Range Sections [TR_Point]

Greene County Parcel Database [PrkRec]

Parks

Golf Courses

Country Clubs

Nature Center

Southwest Missouri Council of Governments

Christian County Hazard Mitigation Plan: [Hlth]

Hospitals

Medical Clinics

Daycare Facilities [DayCare]

Regional Transportation Plan: [MajEmp]

Major Employers

MoDOT Planning Data 2007 [CmSt]

Environmental Science Research Institute (ESRI)

Streetmap USA Network Dataset

Google Maps/Google Earth, Yellow Pages [Shop]

Groceries

Supermarkets

Wal-Mart Supercenters

Malls and Shopping Centers

Target

Lowe's

Home Depot

Office Depot

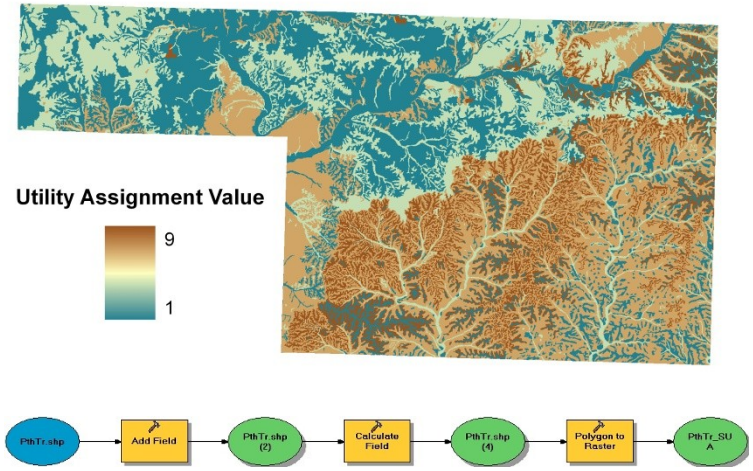
Best Buy

Analyzing Data to Determine the Relative Suitability of Goals

Vector to Raster Conversion. The LUCIS model is designed to take advantage methods and procedures within the Spatial Analyst extension of ArcGIS Desktop and the unique characteristics of the raster data format. The strength of the raster data format as opposed to the vector data format is the ability to perform the simultaneous evaluation of cells from multiple data sets representing coincident locations, rapidly accomplishing complex spatial analysis and overlay. Whereas, performing these tasks with vector data requires the user to continually manage, combine, aggregate and disaggregate multiple layers to form complex polygons or networks (Carr and Zwick, 2007).

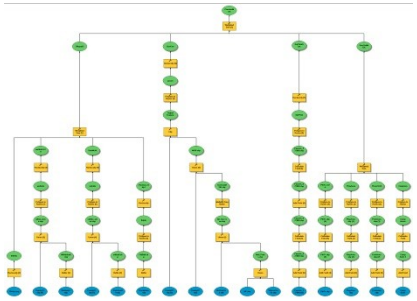
Transforming Nominal Soil Suitability Data to Rescaled Ordinal Utility Value

Original Value	Rank	Reciprocal Rank	Proportion of Utility	Utility Value
Not Limited	1	1/1	1.00*9	9
Somewhat Limited	2	1/2	.5*9	4.5
Very Limited	3	1/3	.333*9	3
Not Rated	4	1/4	.250*9	2.25



Single Utility Assignments. In order for suitability analysis to be meaningful, all of the layers must be reclassified into similar standard intervals to satisfy Chrisman's interaction rule for combining spatial data. Carr and Zwick used intervals from one to nine to assign a "range of utility" to each layer, where one is the lowest suitability and nine is the highest. The method proposed in the LUCIS™ model requires the translation of criterion maps to this common scale whereupon they become single utility assignments (SUA). The level of complexity in determining the range of utility for SUAs varies depending on the level of measurement of the attribute used to define suitability. It is much easier to assign utility values to interval and ratio data that already have known intervals. With this type of data, it is quite common for the modeler to assign the values (Carr and Zwick, 2007).

Combining Relative Suitability's for the Three Major Land-Use Categories

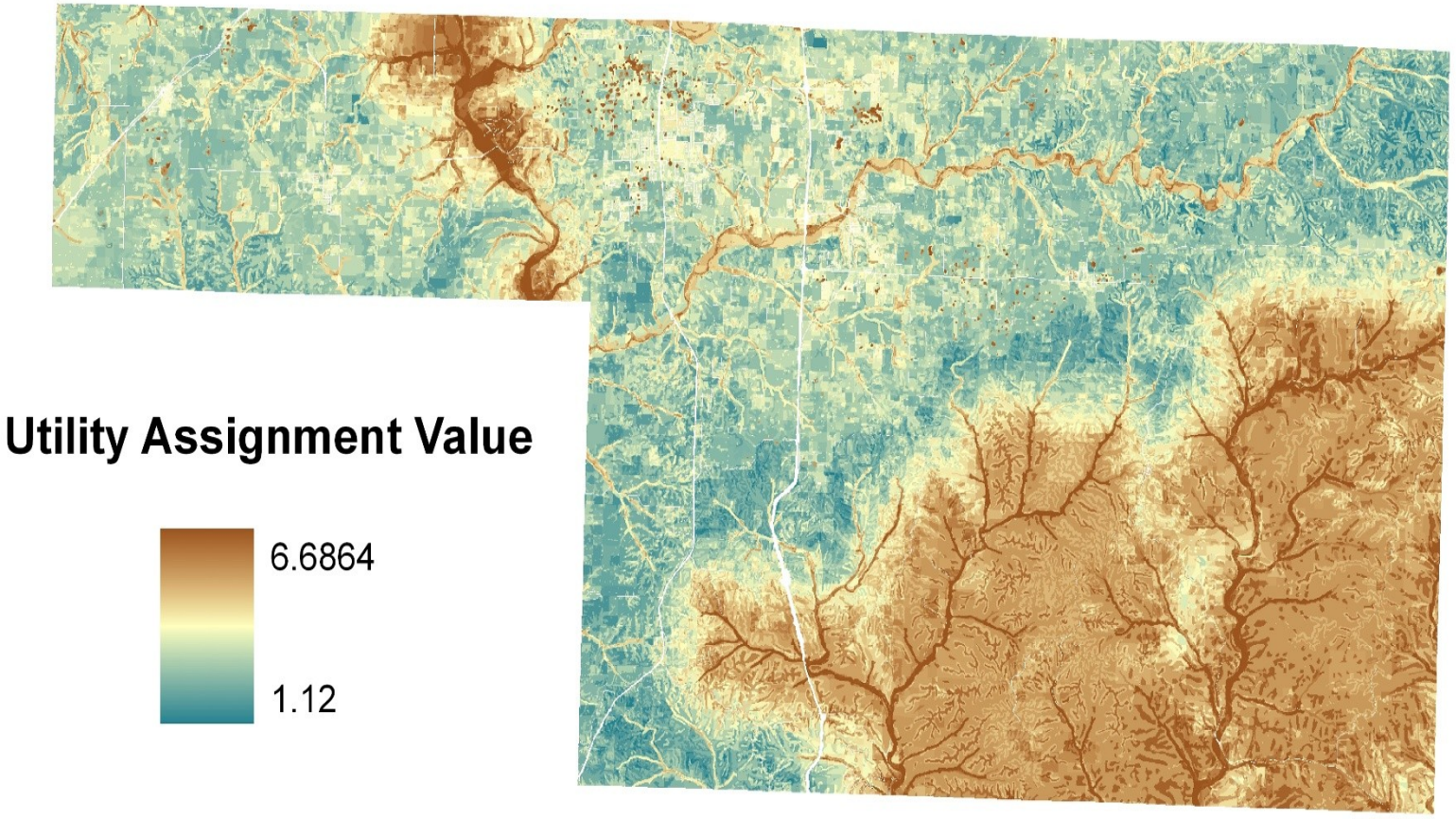


Conservation Multi-Utility Assignment (ConservMUA)

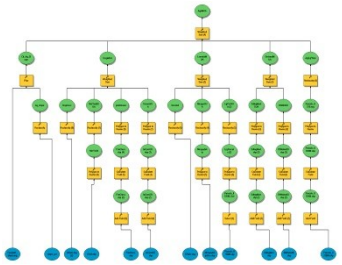
ConservAreasMUA = ([FP]*.25) + ([MoDepCon]*.25) + ([NF]*.25) + ([WCNB]*.25)

RecSoilsMUA = ([CmpArea]*.12) + ([PncArea]*.24) + ([PlayArea]*.16]) + ([PthTr]*.48)

ConservMUA = (ConservAreasMUA*.325) + ([Snkhle]*.325) + ([Wtlnds]*.081) + (PrcVal]*.107)



Agricultural Suitability

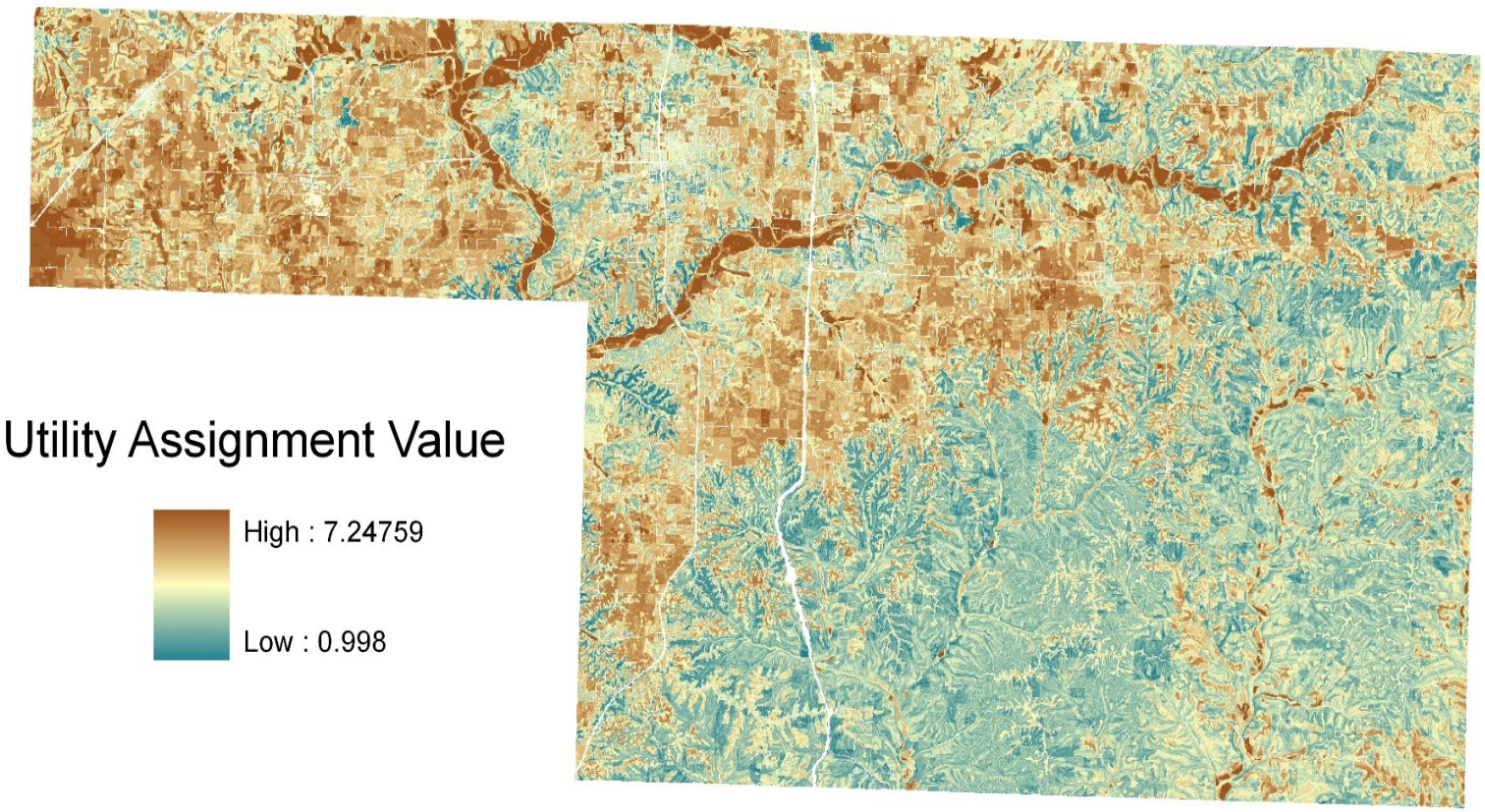


Agricultural Multi-Utility Assignment (AgMUA)

CrplndMUA = ([PrmFrm]*.4) + ([Crplulc]*.4) + ([Yield]*.2)

LvstckMUA = ([Grsslulc]*.5) + ([AgPrc]*.3) + ([Yield]*.2)

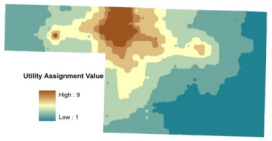
AgMUA = (CrplndMUA*.25) + (LvstckMUA*.35) + ([SdlgMort]*.15) + ([PrcVal]*.25) +



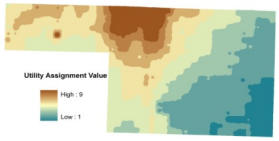
Defining Urban Land-Use Suitability

The Core of the Urban MUA is the use of network based accessibility to various activities; i.e. employment, shopping, etc, weighted according to values from the Citizen Survey. Accessibility to these activities was calculated from an origin/destination matrix generated in ArcGIS Network Analyst using ESRI's Streetmap USA Network Dataset. Township and Range section polygons were converted to points to represent uniformly spaced origins throughout the county. The various destination classes were then weighted in terms of relative attractiveness. Travel time from each origin to each destination was divided into 1 to invert the travel cost value, converting short travel times into higher values. These inverted values were then multiplied by the weight of the particular destination. The summation to each destination was then divided by the total weight of all destinations to produce an accessibility index for each point. A raster surface for each activity was calculated using the inverse distance interpolation method. A measure of proximity to emergency services was calculated in Network Analyst based on service area polygons from fire stations and ambulance facilities. Poximity to water and sewer was calculated using as the crow flys distance from city limits.

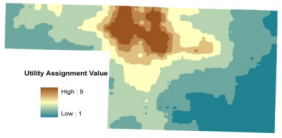
Accessibility to Daycare



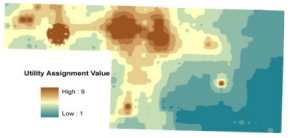
Accessibility to Employment



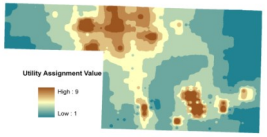
Accessibility to Healthcare



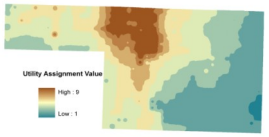
Accessibility to Schools



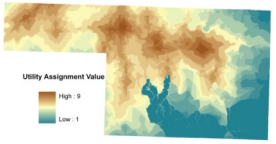
Accessibility to Recreation



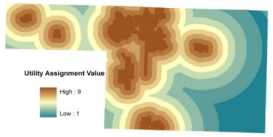
Accessibility to Shopping



Proximity to Emergency Services



Proximity to Utilities



Urban Suitability Model

Urban Multi-Utility Assignment (UrbMUA)

EmergencyMUA = ([FD]* .8) + ([AMB*.2])

SchlDaycareMUA = ([PS]*.7) + ([PRS]*.15) + ([DayCare]*.15)

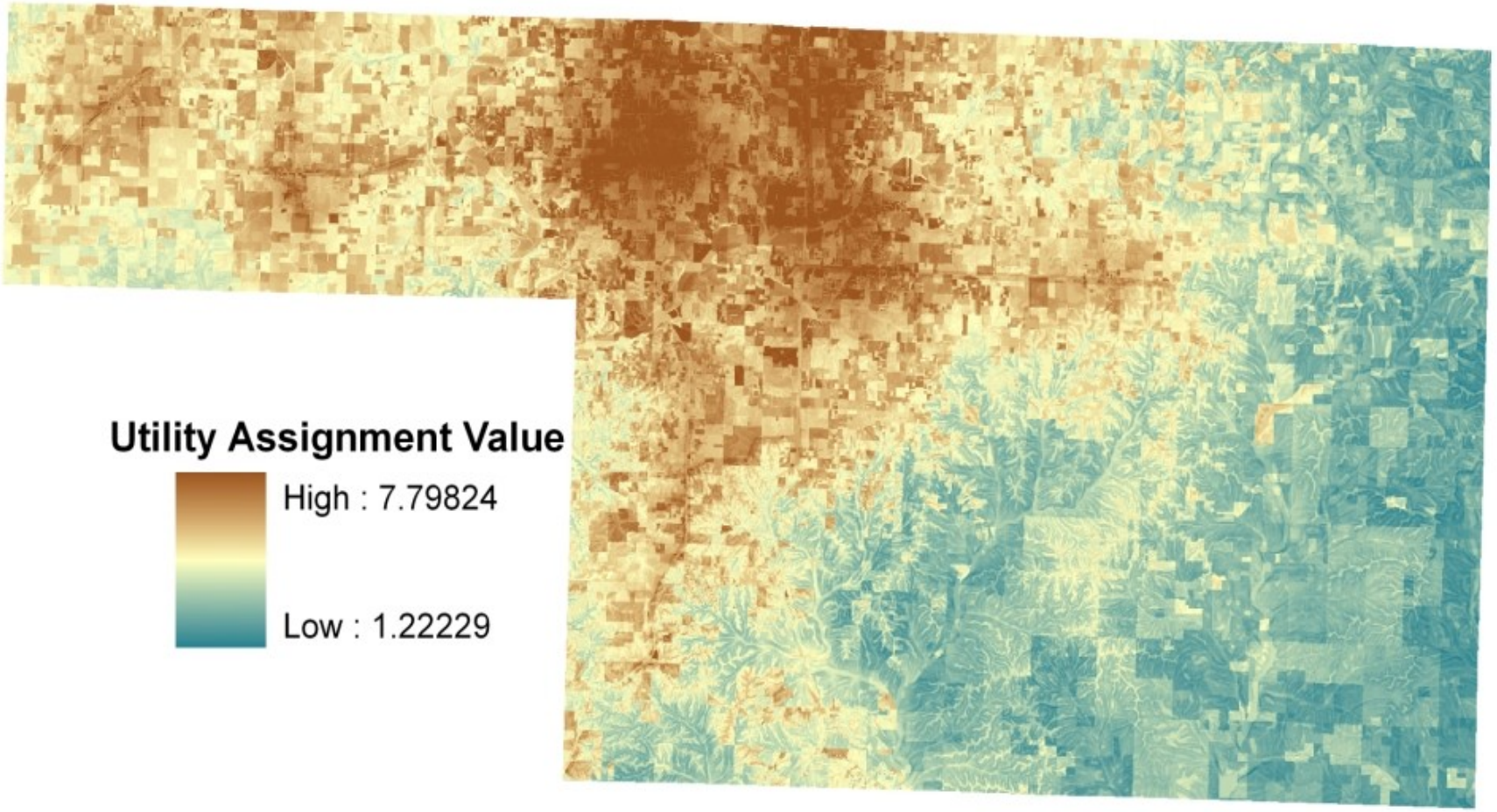
AccessMUA = ([EmergencyMUA]*.158576) + ([Hlth]*.14788) + ([MajEmp]*.139009) + (SchlDaycare*.122091) + ([PrkRec]*.110122) + (ProxUtilities*.107848) + ([Shop]*.090369)

ResSoilsMUA = ([Septic]*.333) + ([RdsStrs]*.333) + ([DWB]*.334)

ResMUA = (AccessMUA*.75) + ([PrcVal]*.15) + (ResSoilsMUA*.1)

ComMUA = ([ComBldg]*.5) + ([CmSt]*.5)

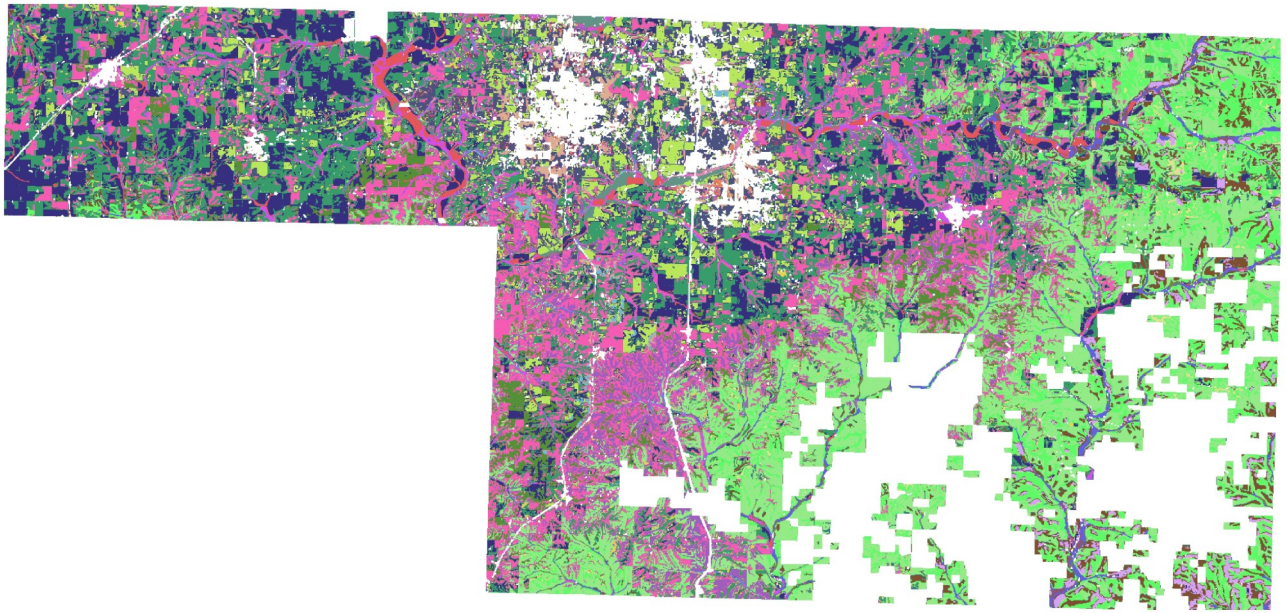
UrbanMUA = (ResMUA*.7) + (ComMUA*.1) + ([PrcVal]*.1) + ([slope]*.1)



Determining Likely Areas of Future Land-Use Conflict

Land-Use Suitability Identification Layer

The AgMUA, ConservMUA, and UrbMUA were all normalized and collapsed from utility values into 3 new classes representing low, medium and high. The AgMUA was reclassified to values in the hundreds place; 100, 200, and 300. The value for the ConservMUA was reclassified to the tens place; 10, 20, and 30. The UrbMUA was similarly reclassified to the ones place. These layers were all added together using the map algebra function in ArcMap. This created 27 unique values representing where agriculture suitability was the greatest; 311, 312, 321, and 322. These values were then reclassified into land most suitable or "preferred" for agricultural endeavors. Similarly, values of 113, 123, 213, and 223 are the cells where Urban suitability wins out. This leaves 15 values, after conservation wins, that represent some form of conflict between land uses. These values are classed together and represented in the land-use conflict map presented on the following page.



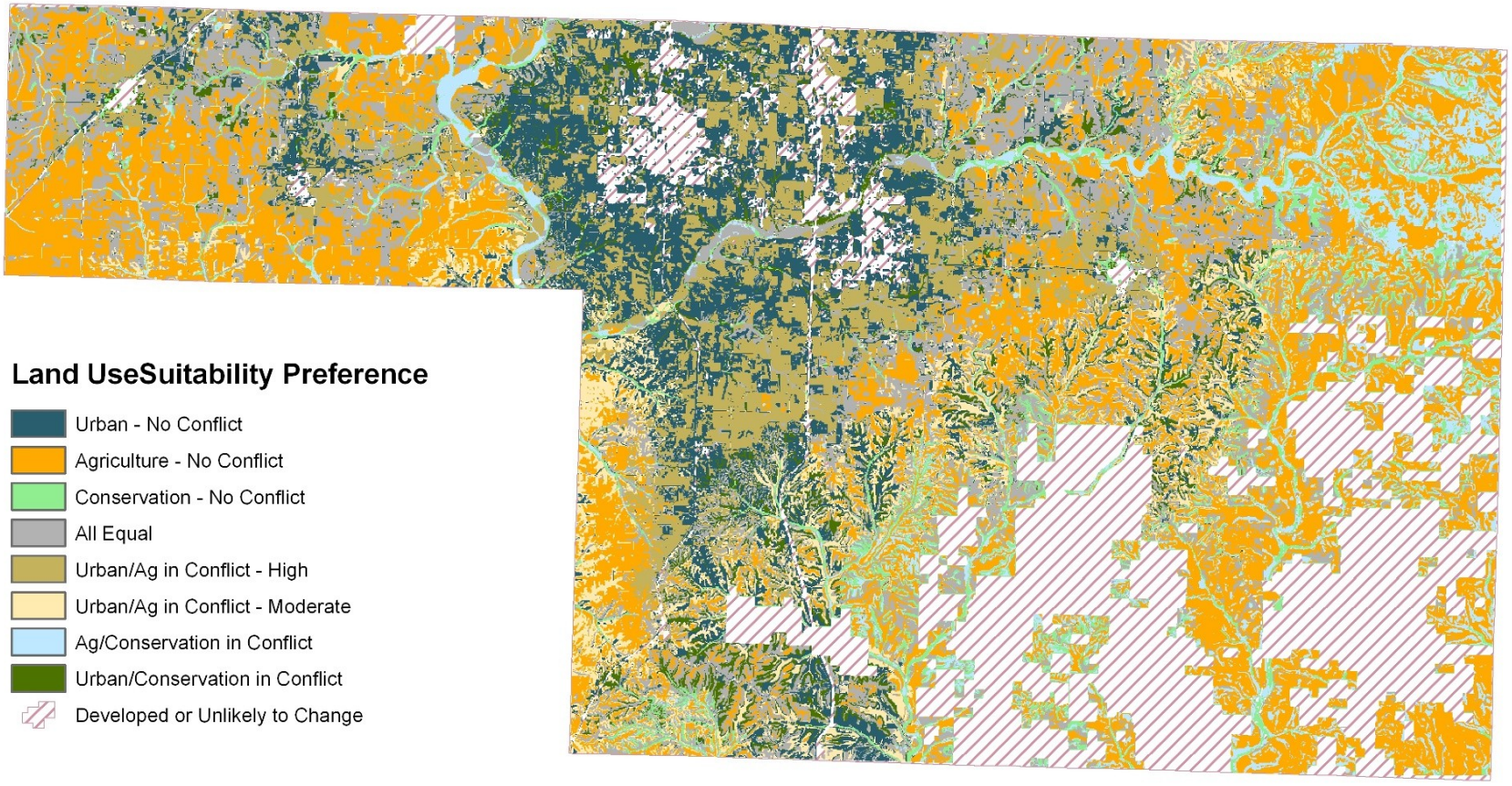
Combined Suitability Values

111	123	212	231	313	332
112	131	213	232	321	333
113	132	221	233	322	
121	133	222	311	323	
122	211	223	312	331	

Results

Land Use Conflict Identification Strategy Model (LUCIS)

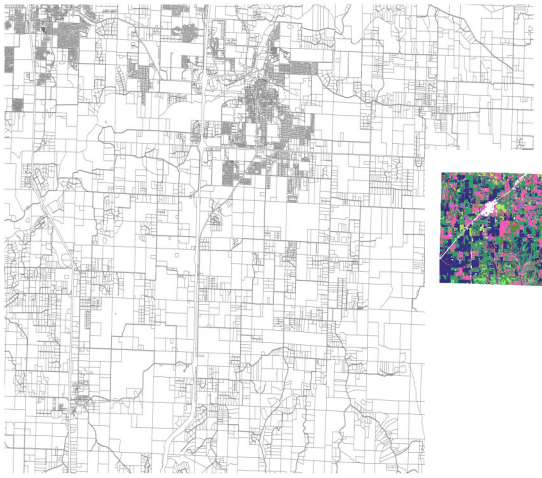
Christian County, Missouri



Prepared by: David Faucett
Prepared for: Christian County Planning and Zoning Dept.
Date: 4/16/2009
Sources: Missouri Spatial Data Information Service; USGS 2005 Land Use/Land Cover Map; Christian County Planning Data; The Southwest Missouri Council of Govts; USDA

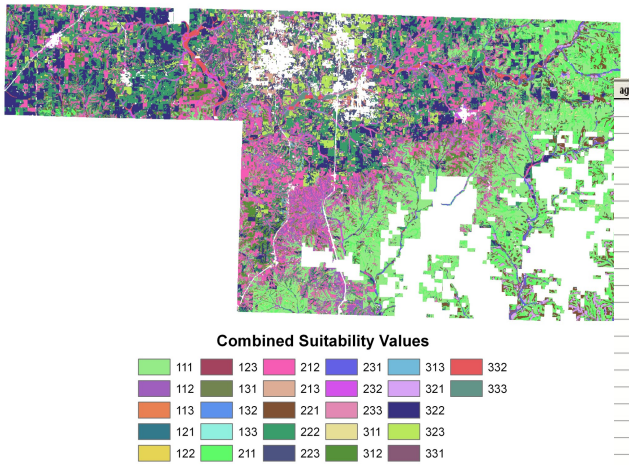
Allocating Future Land-Use

The raster of coded land-use suitability values was used as the base to calculate zonal statistics providing a guide to developing a future land-use map. The Christian County Parcel shapefile was overlaid atop the conflict raster and represents the zones by which to calculate the majority cell value within each parcel. An attribute for each parcel was created for the majority cell value within that respective parcel. This attribute was used along with existing parcel attributes in database queries to determine an appropriate future land-use. In this manner, a future land-use map that attempts to describe a pattern of land-use that balances the value of agricultural productivity, the conservation of land suitable for life sustaining ecological processes and the need for economic growth and development can be used as a guide to more sustainable outcomes for future generations.



Parcel Data

LUCIS™ Value

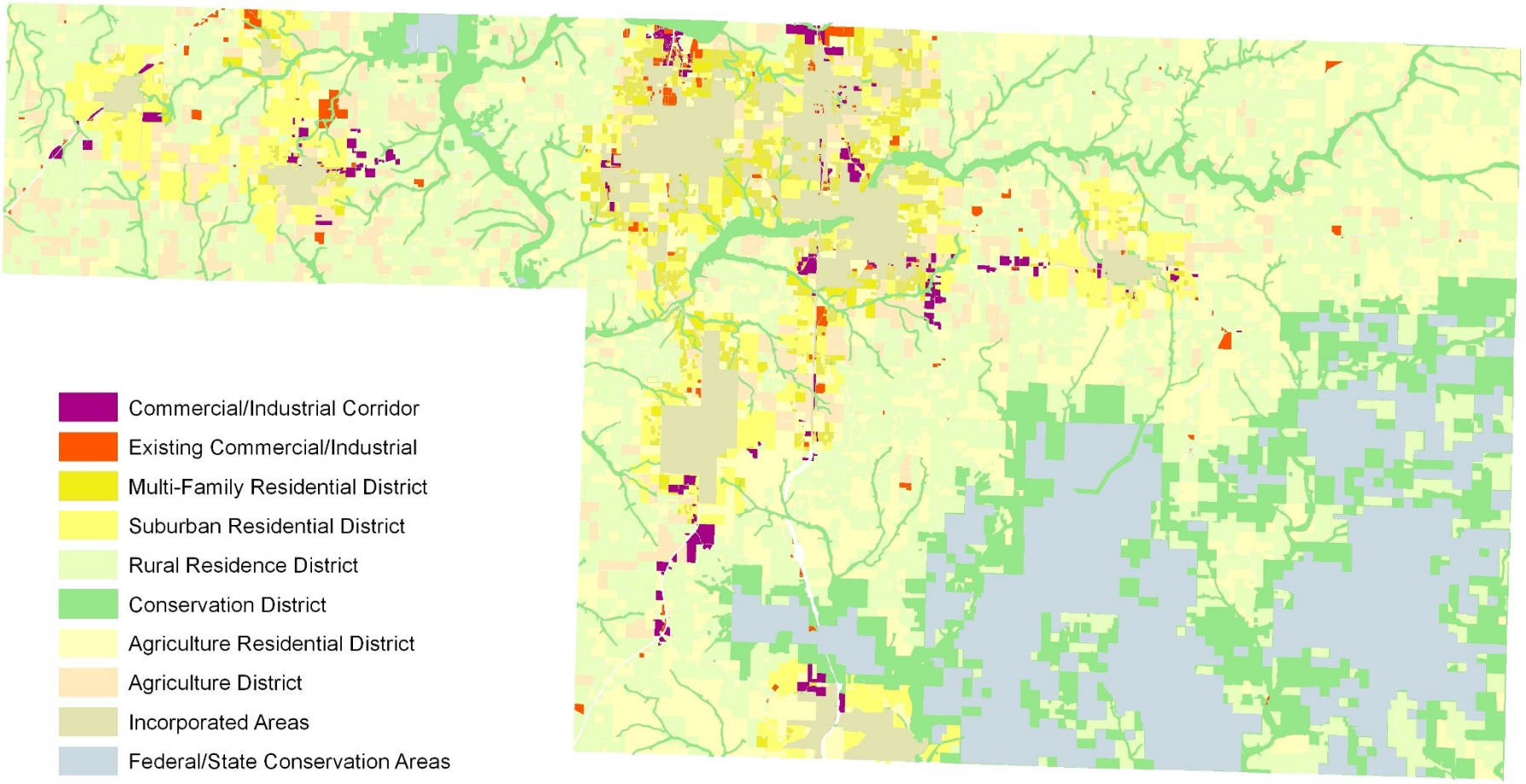


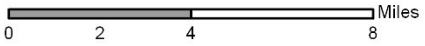
New Parcel Attribute

ag7_acre	ag8_acre	ag90_acre	land_type	appr_res	appr_ag	appr_comm	Appr_Val	AV_Val	LUCIS_VAL
0	0	0	RL	10000	0	0	10000	2382.513705	213
27	0	0	RL	122100	7100	0	129200	3114.519946	212
8.02	0	0	RL	0	600	171400	172000	19106.920815	212
0	6.1	0	RL	0	1700	0	1700	114.66544	223
0	0	0	RL	67600	0	0	67600	12681.765603	222
6.2	1	0	RL	0	2700	0	2700	148.018308	212
0	0	0	RL	230500	0	0	230500	61573.568068	222
0	0	0	RL	44900	0	0	44900	14119.641027	222
0	0	0	RL	103900	800	0	104700	20299.161244	222
0	0	0	RL	30700	900	0	31600	6255.904158	122
0	4	0	RL	0	1100	0	1100	124.425072	222
15	14	0	EX	0	3200	0	3200	76.951066	122
35	5	0	EX	0	2800	0	2800	68.531761	222
15	15	0	EX	0	3000	0	3000	80.316521	222
26.21	27.6	0	RL	0	6100	0	6100	75.300966	222
0	0	0	RL	5200	0	0	5200	4384.158629	222
0	3	0	RL	16700	700	0	17400	2024.70057	232
0	0	0	EX	0	23400	0	23400	146.634378	221
6	16	0	RL	0	3500	0	3500	86.742702	121
0	0	0	RL	127300	33800	0	161100	4597.005001	223
0	0	0	RL	0	400	0	400	117.743483	113
11.5	0	0	RL	14500	1200	0	15700	1143.30735	213
0	0	0	RL	127900	0	0	127900	38352.935322	213

Record: 0 Show: All Selected Records (0 out of 34101 Selected) Options

Christian County, Missouri Future Land-Use Map





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