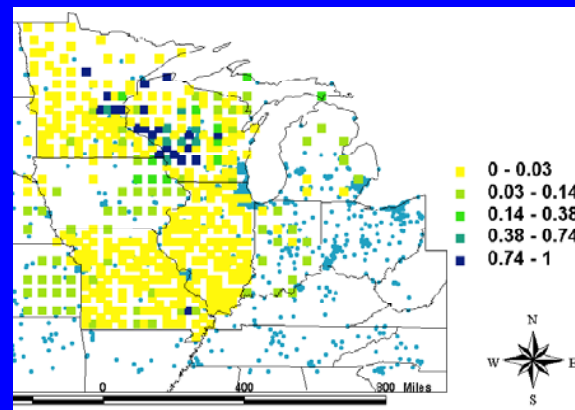




REMOTELY SENSED INDICATORS OF MICRO-CLIMATE IN PREDICTING NEW AREAS OF HUMAN RISK OF LYME DISEASE USING SPATIAL STATISTICS AND ARTIFICIAL NEURAL NETWORKS



A PRESENTATION TO THE SUMMER COLLOQUIUM ON CLIMATE AND HEALTH
JULY 23, 2004, NCAR, BOULDER COLORADO
RUSSELL BARBOUR PH.D.
VECTOR ECOLOGY LABORATORY
YALE SCHOOL OF MEDICINE
NEW HAVEN CT.

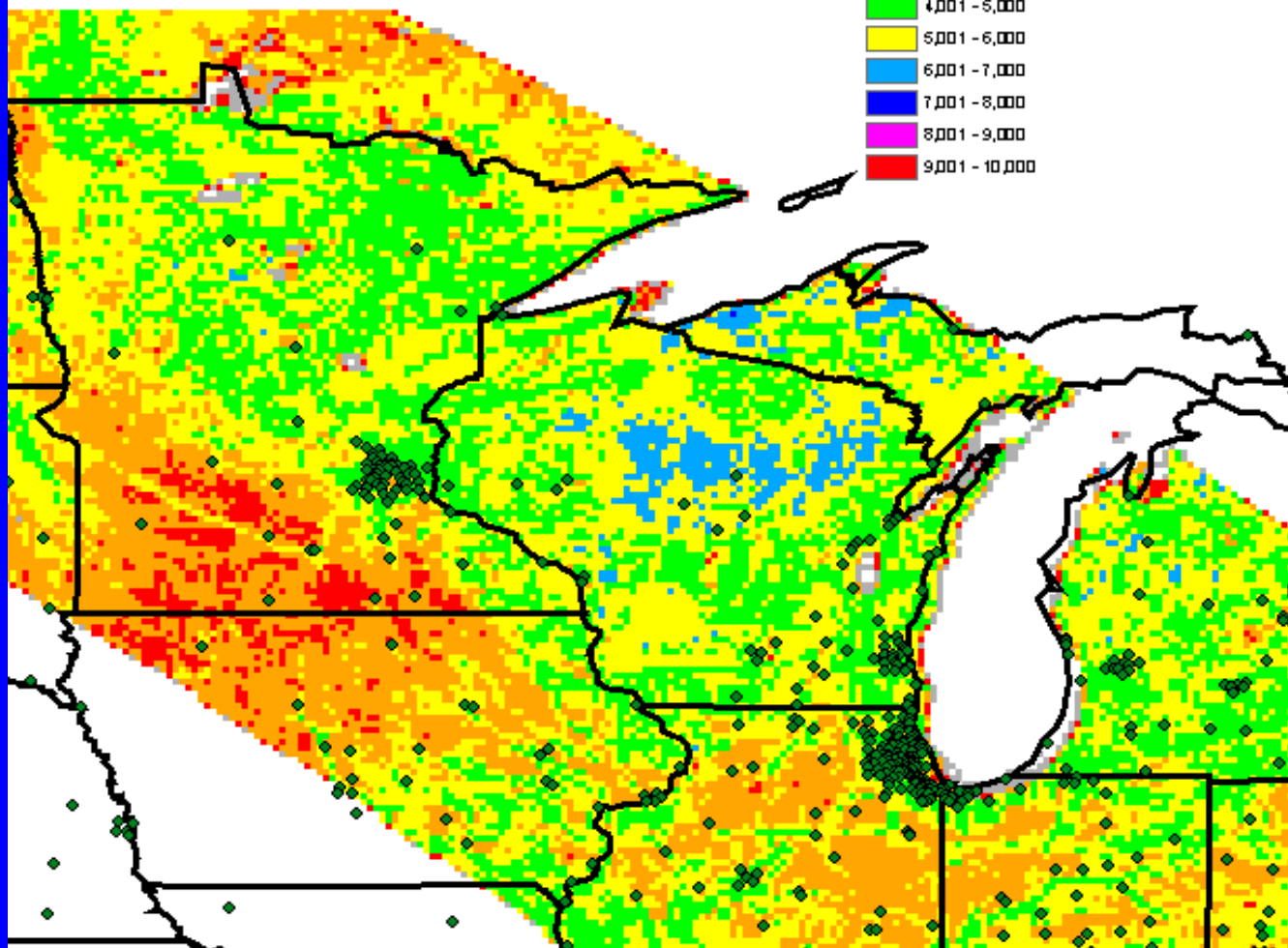
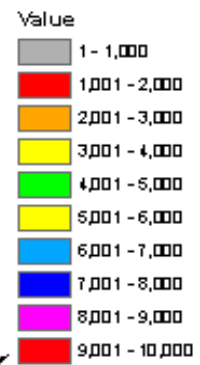
PROBLEM STATEMENT

- **HUMAN CASE DATA HAS BEEN PROVEN AN UNRELIABLE INDICATOR OF LYME DISEASE RISK**
- **UNDER REPORTING, MIS-DIAGNOSES, AND OVER REPORTING DISTORT HUMAN CASE DISTRIBUTION**
- **COLLECTION AND TESTING OF INFECTED NYMPHS COSTLY**

NEW APPROACH TO RISK ESTIMATION AND PREDICTION

- INTEGRATE HUMAN CASE DATA WITH LANDSCAPE INDICATORS OF THE NIDALITY OF INFECTION OF *Borrelia burgdorferi*
- BUILD DATA LAYERS FROM REMOTELY SENSED VEGETATION INDICATORS, PUBLISHED CANINE SEROPREVALENCE AND PREVIOUS HUMAN CASE DATA

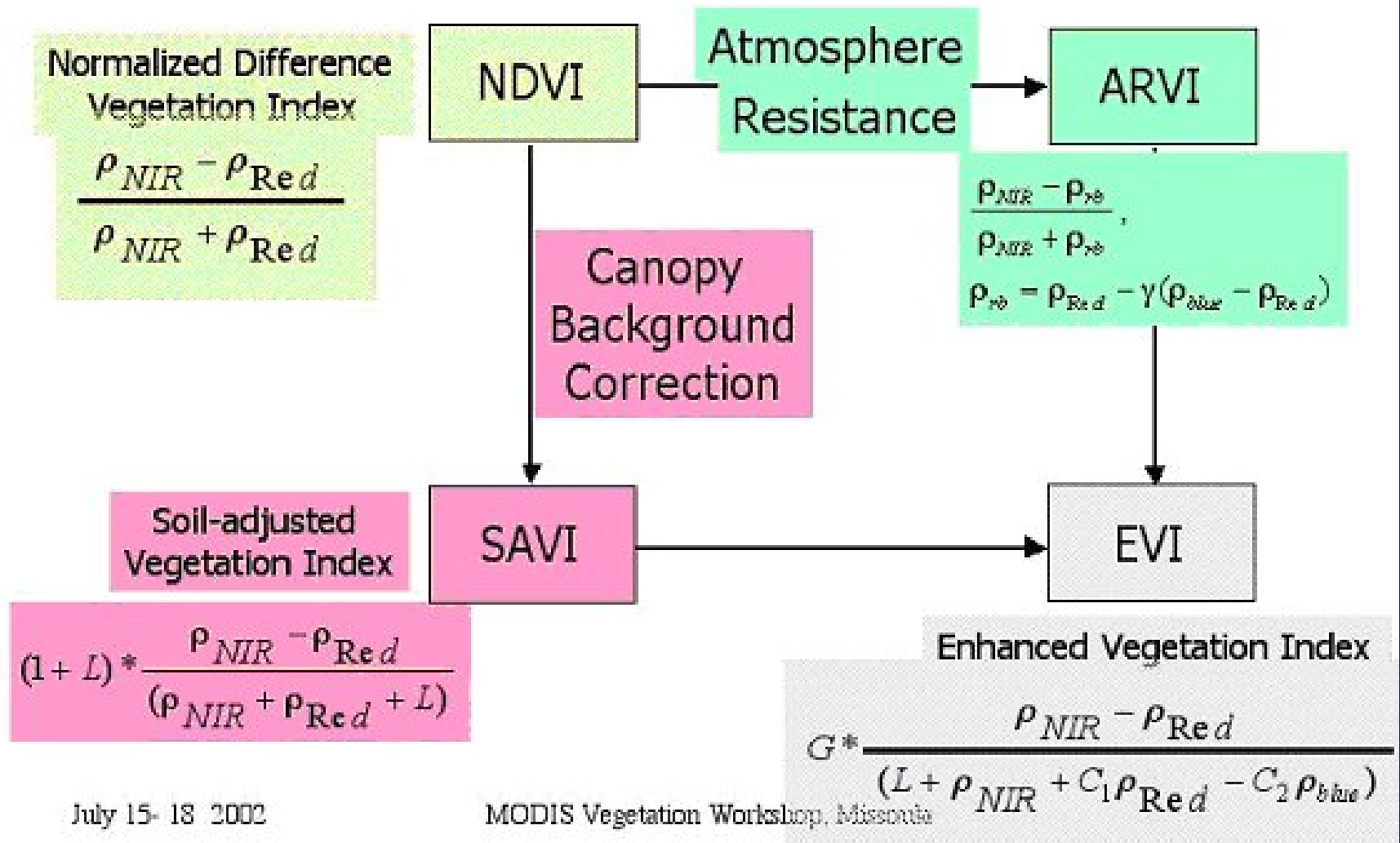
ENHANCED VEGETATION INDEX MODIS MAY 25 2001



EVI AS A FACTOR IN ESTIMATING LYME DISEASE RISK

- **MORE SENSITIVE TO PERIODS OF LIGHT VEGETATION , SPRING AND FALL WHEN NYMPHAL AND ADULT TICKS ARE ACTIVE**
- **DISTINGUISHES BETWEEN WOODED SUBURBS AND TRUE FORESTS DURING THIS TIME PERIOD**
- **IDENTIFIES DISCONTINUITY IN LANDSCAPES BETTER THAN NDVI**

MODIS Vegetation Indices



ENHANCED VEGETATION INDEX MODIS MAY 25 2001

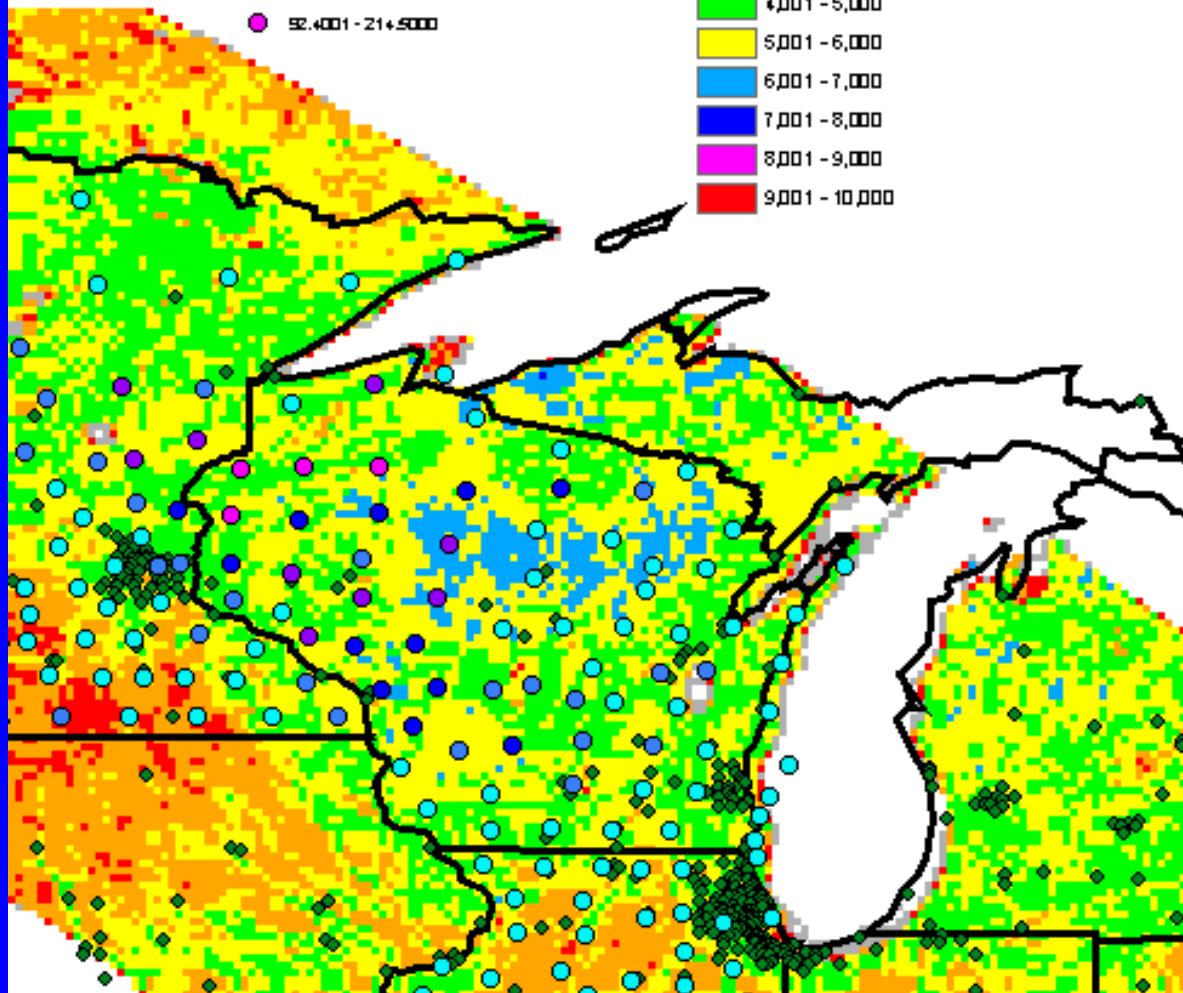
HUMAN CASES BY COUNTY 1992

RATES2

- 0.0000 - 5.1000
- 5.1001 - 18.5000
- 18.5001 - 42.1000
- 42.1001 - 92.4000
- 92.4001 - 214.5000

Value

- 1 - 1,000
- 1,001 - 2,000
- 2,001 - 3,000
- 3,001 - 4,000
- 4,001 - 5,000
- 5,001 - 6,000
- 6,001 - 7,000
- 7,001 - 8,000
- 8,001 - 9,000
- 9,001 - 10,000



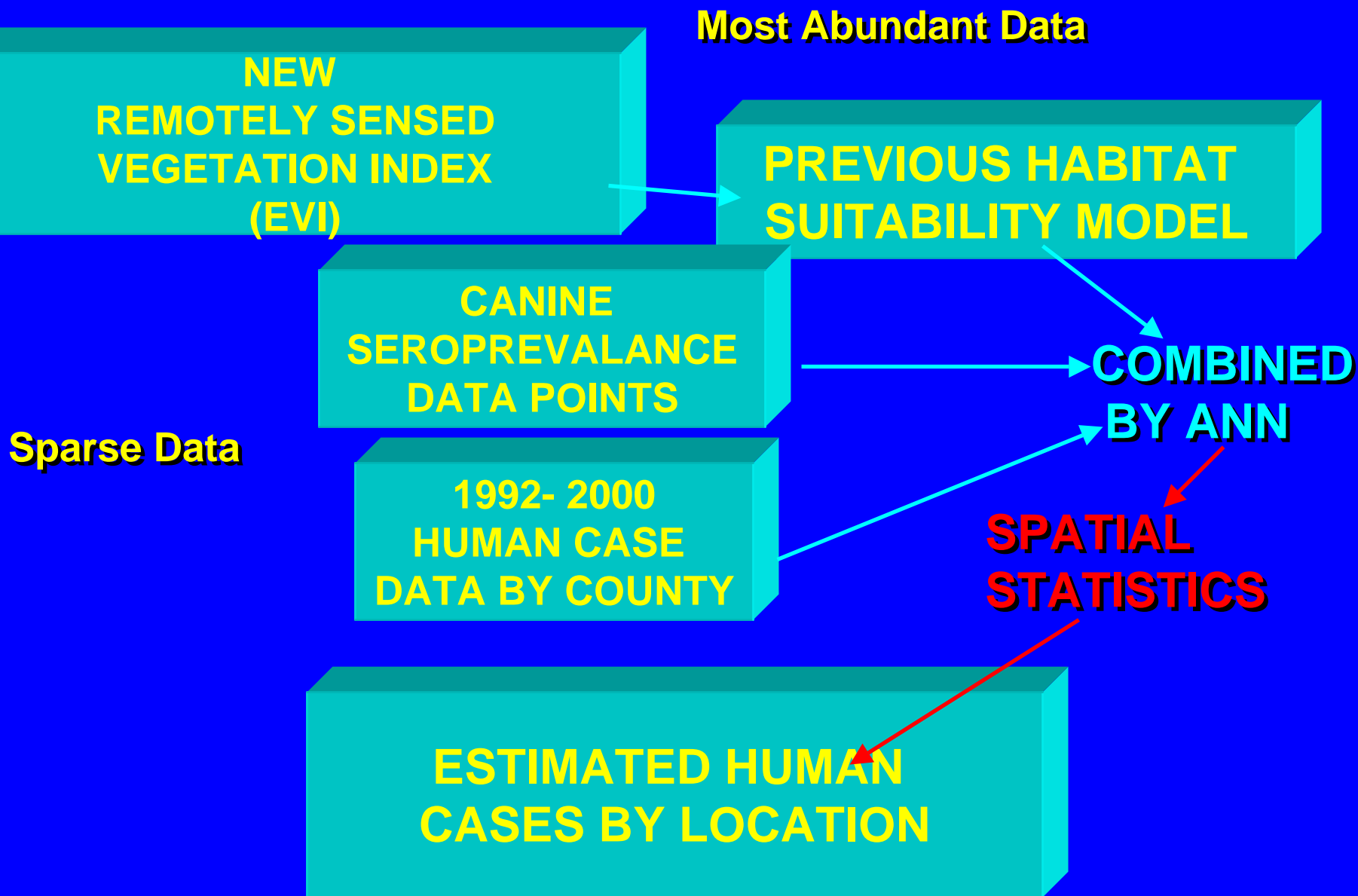
RELATIONSHIP BY DATE BETWEEN HUMAN CASES AND EVI BY MOVING WINDOW ANALYSIS

YEAR	MODIS EVI DATES	CORRELATION
1992	MAY25 2001	.12
	JULY 28 2001	.01
1993	MAY 25 2001	.11
	JULY 28 2001	.02
1994	MAY 25 2001	.18
	JULY 28 2001	.06
1995	MAY 25 2001	.14
	JULY 28 2001	.06
1996	MAY 25 2001	.16
	JULY 28 2001	.06
1997	MAY 25 2001	.14
	JULY 28 2001	.06
1999	MAY 25 2001	.17
	JULY 28 2001	.06
2000	MAY 25 2001	.20
	JULY 28 2001	.06

MOVING WINDOW ANALYSIS OF HUMAN PREVALENCE AND LANDSCAPE INFECTION INDICATORS

YEAR	CROSS-CORRELATION BY MOVING WINDOW ANALYSIS
1992	.13
1993	.16
1994	.12
1995	.12
1996	.14
1997	.20
1998	.17
1999	.17
2000	.20

MATHEMATICAL DATA INTEGRATION



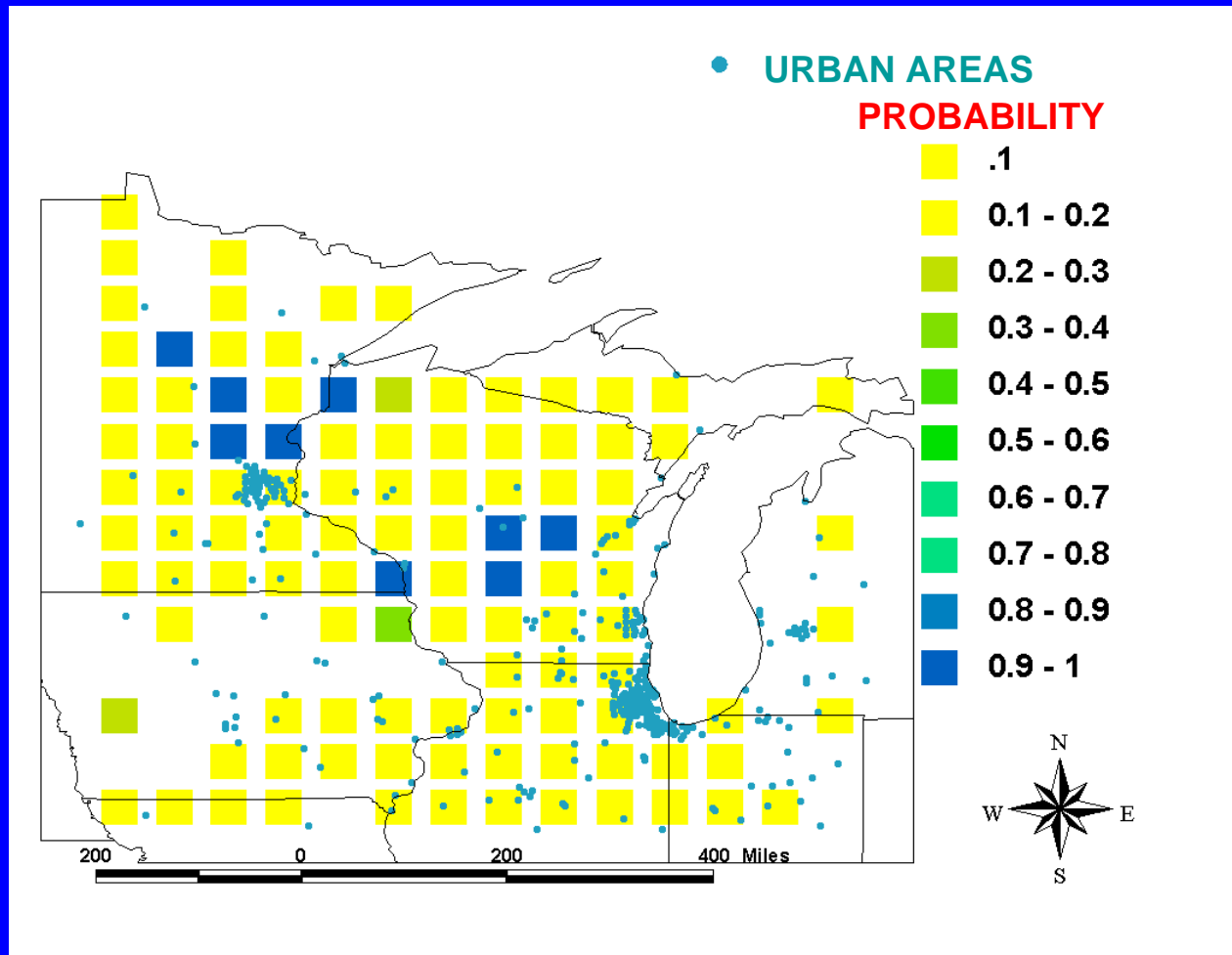
**PREDICTIVE VALUE OF 1995 MID-WESTERN CASE DATA
WHEN INTEGRATED WITH PREVIOUS YEARS AND
LANDSCAPE INDICATORS OF INFECTION BY MULTILAYER
ARTIFICIAL NEURAL NETWORKS**

YEAR	PREDICTIVE VALUE
1995	0.9986
1996	0.9007
1997	0.8420
1998	0.8800
1999	0.8779
2000	0.8323

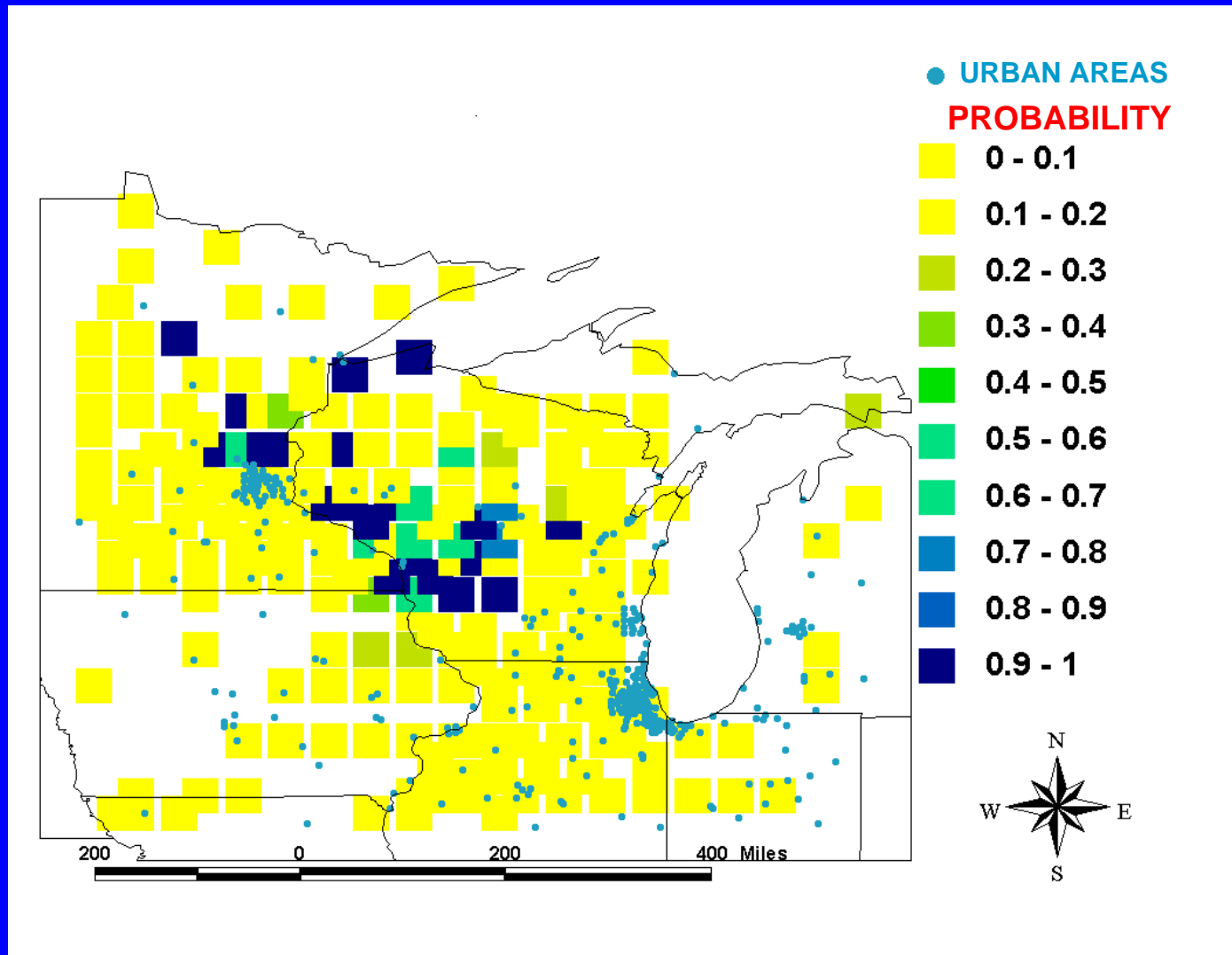
**PREDICTIVE VALUE OF 1998 MID-WESTERN CASE DATA
WHEN INTEGRATED WITH PREVIOUS YEARS AND
LANDSCAPE INDICATORS OF INFECTION BY MULTILAYER
ARTIFICIAL NEURAL NETWORKS**

YEAR	PREDICITIVE VALUE
1998	.99
1999	.99
2000	.91

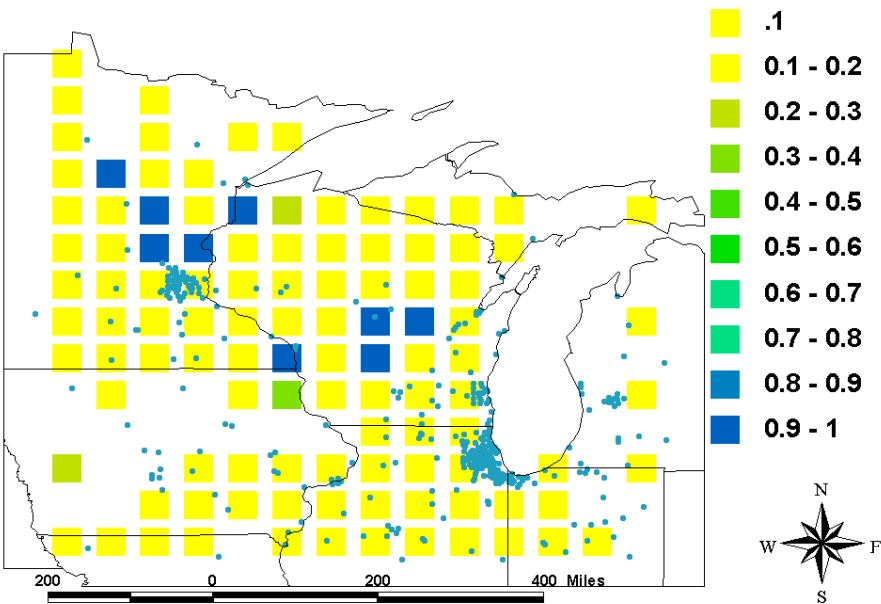
PROBABILITY OF HUMAN PREVALENCE HIGHER THAN 25/100,000 FROM 1992 HUMAN CASE DATA AND LANDSCAPE INFECTION INDICATORS



PROBABILITY OF HUMAN PREVALENCE HIGHER THAN 25/100,000 FROM 2000 HUMAN CASE DATA AND LANDSCAPE INFECTION INDICATORS



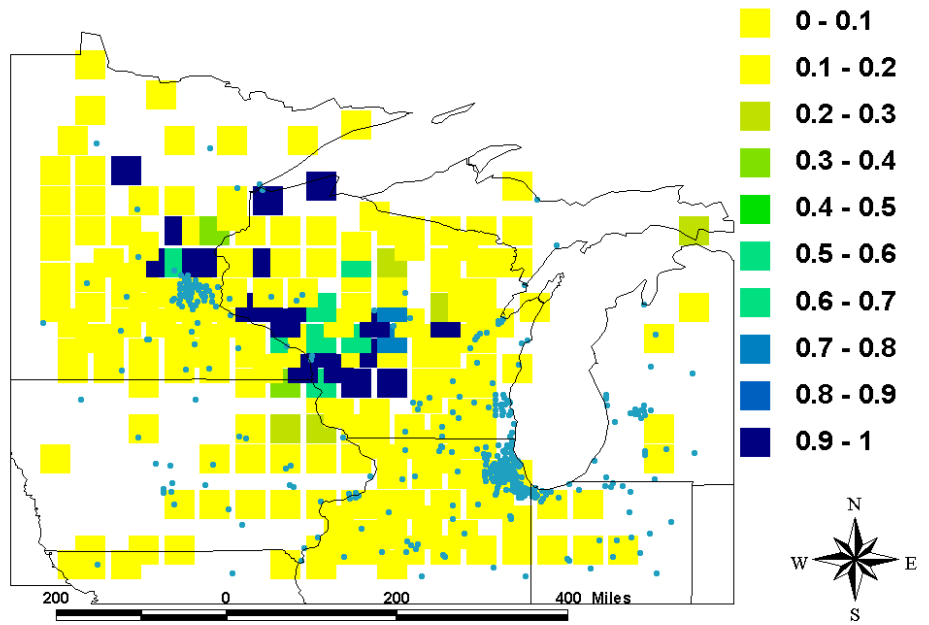
● URBAN AREAS



← 1992 PROBABILITY OF HIGH PREVALENCE

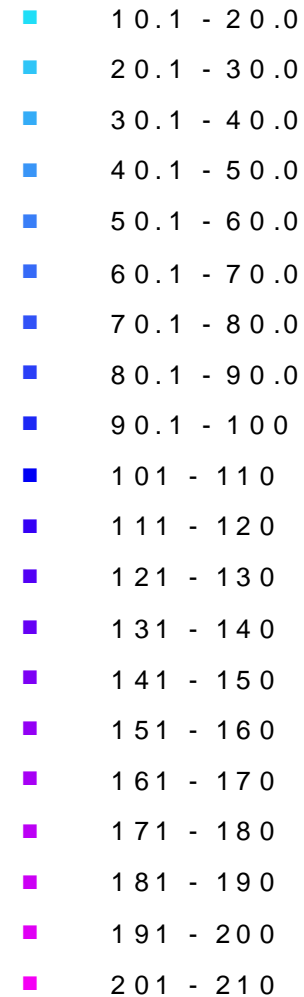
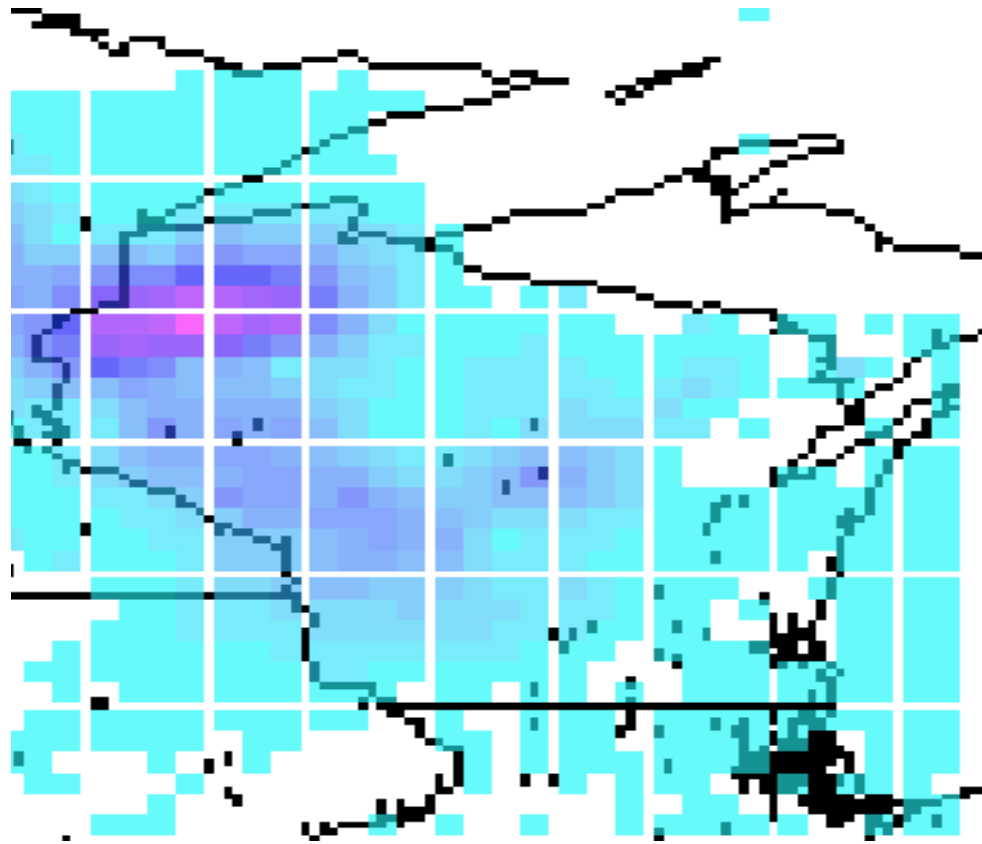
2003 PROBABILITY OF HIGH PREVALENCE →

● URBAN AREAS



MOST LIKELY 2003 HUMAN CASES PER 100K ESTIMATED FROM 2000 CASE DATA AND LANDSCAPE INDICATORS SPATIAL STATISTICS AND ANN

CASES PER 100K



WEAKNESS

- **VEGETATION DATE TOO SPECIFIC**
- **LARGE AREAS OF UNCERTAINTY**
- **NO QUALITY CRITERIA FOR ORIGINAL CASE DATA**
- **“NOISE” STILL PRESENT**

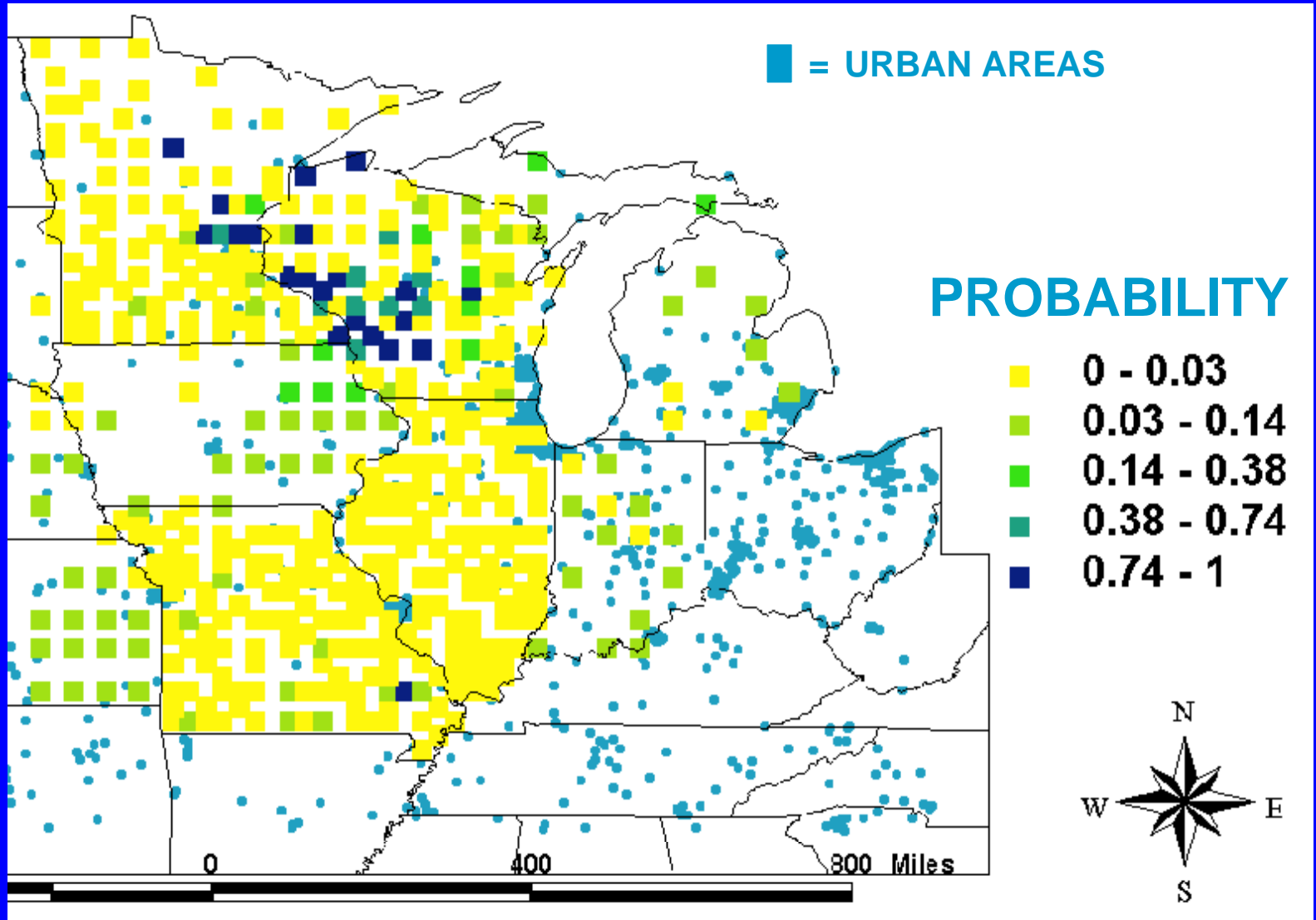
STRENGTHS

- **HUMAN CASE DATA LINKED TO NIDALITY OF INFECTION**
- **REASONABLE PREDICTIONS OF HUMAN RISK POSSIBLE**
- **THREE YEAR ADVANCE OF INFECTION WALL APPEARS VISIBLE**

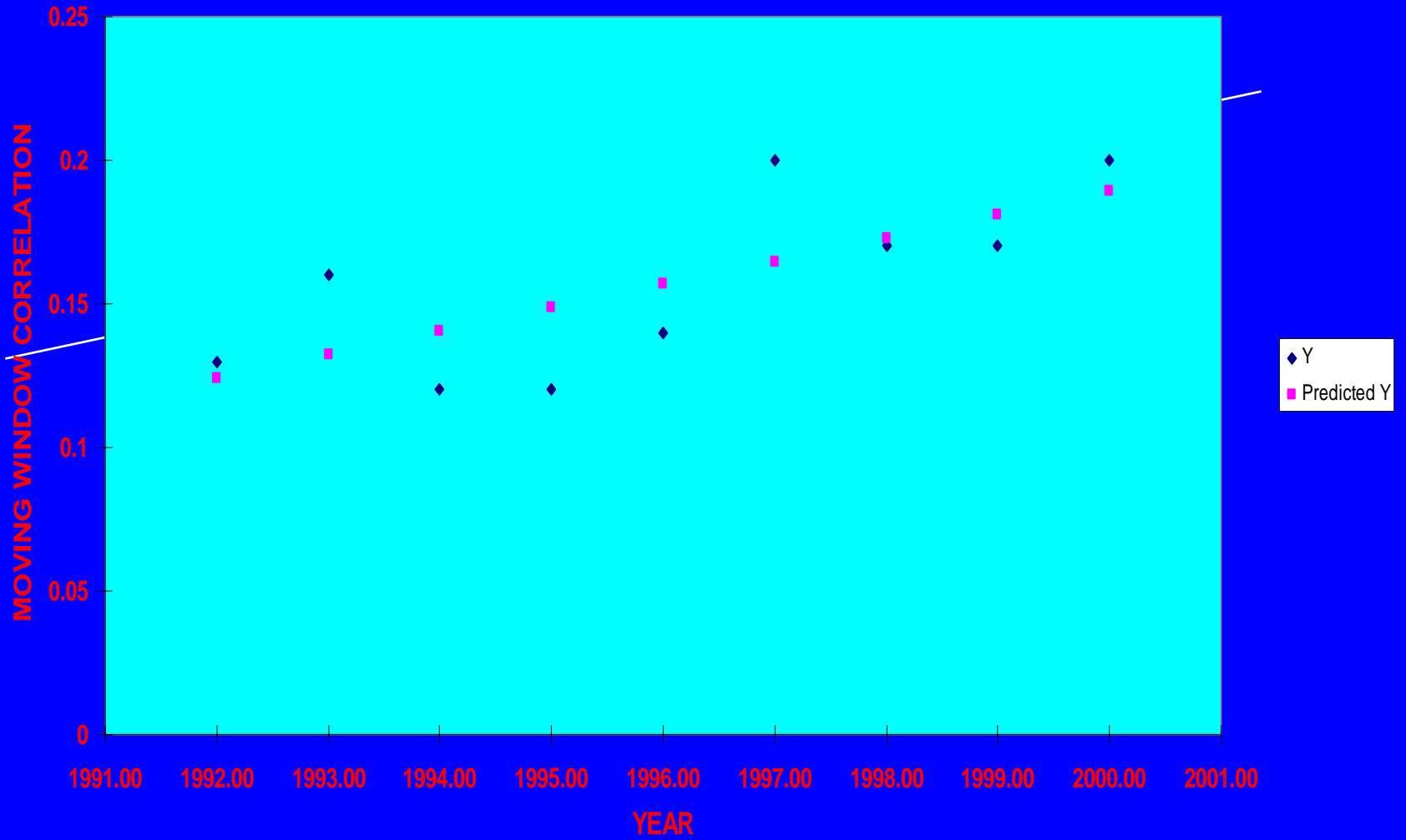
FUTURE RESEARCH

- **CUBIC SPLINE REGRESSION OF ALL HUMAN CASE DATA TO REMOVE NOISE**
- **ADDITION OF NEW CANINE SEROLOGY DATA FROM MARTA ET AL 2001**
- **GEOGRAPHIC EXTENSION OF MODEL**
- **CALCULATION OF THE RATE OF INFECTION SPREAD , CURRENTLY ABOUT 6 KILOMETERS A YEAR, BASED ON PROBABILITY MODELS, NOT CASES**

PROBABILITY OF HUMAN PREVALENCE HIGHER THAN 25/100,000 FROM 2000 HUMAN CASE DATA AND LANDSCAPE INFECTION INDICATORS



CROSS CORRELATION PREVANCE AND LANDSCAPE INDICATORS OF *B. BORRELIA* INFECTION



MATHEMATICAL DATA INTEGRATION

