IMPROVEMENTS TO NONROAD MODEL INPUTS FOR MIDWESTERN STATES

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ABSTRACT

The purpose of this project was to develop data specific to Midwest region states to improve upon EPA's default 2002 nonroad construction and agricultural engine emission estimates. In EPA's NONROAD emissions model, state-level populations and activity for construction and agricultural categories are derived from national sources of data, and county-level activity is estimated using surrogate indicators that may not always correlate well with local equipment use. Information was collected via survey methods, and from publically available sources of data, to develop local model inputs for equipment populations, engine characteristics, and spatial and temporal activity. These revised inputs will be used to support future Lake Michigan Air Directors Consortium (LADCO) regional emissions modeling efforts.

INTRODUCTION

This paper describes the results of a study to improve EPA default 2002 nonroad construction and agricultural engine emission estimates for select states in the Midwest region. The EPA's NONROAD emissions model relies on county allocations of national equipment population and activity data to estimate county-level emissions. Because NONROAD estimates county-level emissions using surrogate indicators that may not always correlate well with local equipment use, LADCO commissioned a study to develop Midwest region-specific equipment population, engine characteristic, and spatial and temporal activity model inputs.

To develop local data for the construction category, a telephone survey of construction equipment owners and operators was performed, targeting businesses which are most likely to use these types of equipment. The survey results were used to develop more representative estimates of the types and number of equipment used, as well as information on the use of the equipment (i.e., during the day/week or throughout the year). For the agricultural equipment category, county-level diesel fuel consumption estimates were developed to improve upon the NONROAD model's methods for spatially allocating agricultural equipment activity. Weekly and monthly diesel fuel consumption were also estimated for each state to improve upon the monthly activity profile defaults in the NONROAD model. This study provides improvements to the NONROAD model inputs for Indiana, Illinois, Michigan, Ohio, and Wisconsin for construction equipment, and for these five states plus Iowa, Minnesota, and Missouri for agricultural equipment. Comparisons are provided between the data developed in this study and NONROAD model defaults. The data developed in this study will support LADCO in future regional emissions modeling efforts.

CONSTRUCTION EQUIPMENT

E.H. Pechan & Associates, Inc. (Pechan) and its subcontractor Population Research Systems (PRS) recently completed a survey of construction activity for five Midwest region states. The survey instrument was designed to request information on: 1) the types and number of equipment used; 2) frequency of use and time of use (e.g., during the day/week or throughout the year); and 3) engine size. The survey also requested the number of employees for use in developing scaling factors to estimate equipment populations for the complete universe of expected users.

We purchased 5,550 commercial sample points from a sample frame that consisted of all listed business within the states of Indiana, Illinois, Michigan, Ohio, and Wisconsin corresponding to the following seven categories:

- Heavy Construction Contractors: Standard Industrial Classification (SIC) code 16
- Specialty Trade Contractors, 4-digit SIC codes:
  - 1771 - Concrete Work
  - 1794 - Excavation Work
  - 1781 & 1795 - Water Well Drilling & Wrecking and Demolition Work
- Rental Equipment: SIC codes 5082, 7353, 7359
- Landfills: SIC code 4953
- Mining (Metals, coal, and nonmetallic): SIC codes 10, 12, and 14.

The challenge with the construction category is that there can be many potential users (across several SIC groups) of a given equipment type. The surveyed SIC groups were selected based on a prioritization that identified fourteen diesel SCCs contributing to 95 percent of the total construction equipment NO_x emissions in the LADCO region (based on NONROAD2002a). The majority of these fourteen equipment categories are larger equipment that are expected to be used for roadway and other heavy construction activities. We used a Computer-Assisted Telephone Interview (CATI) approach to survey the targeted industries. While there were no formal quota cells for the study either by category or state, we attempted to complete approximately 55 interviews in each of the seven SIC categories. Each record was "flagged" based on SIC code to identify the category from which it was drawn.

A more limited set of questions was asked of the rental equipment companies (SIC codes 5082, 7353, 7359). These companies typically do not keep records concerning operating practices of their rental equipment. We were primarily interested in obtaining information on the number of pieces of equipment from the rental firms, because of the volume of equipment that these firms handle. In asking questions of the construction equipment users, we requested that they report the number of pieces of owned equipment separately from rented equipment, to avoid double counting.

Equipment-specific fuel information was requested as a percentage of the total equipment population that the respondent used or rented. These percentages were then applied to the total count of equipment to estimate gasoline, diesel, liquefied petroleum gasoline (LPG), or compressed natural gas (CNG) engines. Data corresponding to electric-powered equipment were removed from the analysis.

Survey Results

Questions concerning weekly and hourly operations were asked in relation to the operation of all equipment by the respondent, and not specific to a certain equipment type. Questions on annual and seasonal usage, equipment populations, and equipment horsepower were asked for each of 26 types of equipment, if a respondent owned/leased this type of equipment. For all activity variables, responses were weighted by the number of pieces of equipment for which respondents were providing information, as well as by a weighting factor of the surveyed to the regional employment of their SIC grouping.

A discussion of the results for weekly and hourly temporal profiles, annual and seasonal use, as well as equipment populations, are presented in the following sections. For all of these variables, final survey results are compared to the NONROAD2002a[1] model defaults.

Weekly and Hourly Temporal Profiles

The survey requested information on the operation of equipment during six 4-hour time periods during a typical weekday and a typical weekend day. Percentage of operators working for each time period were weighted by the associated number of equipment owned and rented by the respondent, to give more weight to those respondents owning or leasing a larger number of equipment. Based on these percentages, it was estimated that operators were almost 4 times as likely to operate equipment on the weekdays than the weekend days. Table 1 shows this comparison to the default NONROAD model weekly profile, which assumes that construction equipment is 2 times as likely to be operated during the weekday than a weekend day[2].

The weekday diurnal profile developed from the survey results is shown in Figure 1, and compared to EPA's diurnal profile for construction equipment, as listed in EPA's Emission Modeling Clearinghouse[3]. A weekend day temporal profile was also developed from the survey. The survey results do not provide information on how the activity may vary within each 4-hour period, which is reflected in EPA's default profile. Although EPA's NONROAD model does not have the ability to calculate hourly emissions, LADCO may use the diurnal profiles for their own modeling efforts.

Annual Hours of Use and Seasonal Activity

We estimated equipment-specific annual hours of use by multiplying hours of operation per week by weeks of operation per year. The sample obtained per equipment type was not deemed sufficient for replacing the NONROAD defaults by SCC. As such, we examined the weighted average annual use for all SCCs combined from the survey, and compared that to annual use across all applications in the NONROAD model. From these averages, we developed a value of 1.2 that represents the ratio of the average survey to the NONROAD model annual use. Annual hours of use per year were then adjusted by increasing values 20 percent for all construction SCCs in NONROAD.

Based on responses to questions concerning operation during the four seasons of the year, we estimated the average seasonal percentages for each equipment type. The NONROAD model includes a single seasonal allocation for all construction equipment, regardless of engine or application[4]. We evaluated responses for groups of equipment, since, similar to the data obtained for annual hours of use, the sample size obtained per equipment type was not deemed sufficient. We first evaluated the data across all applications, and also examined statistical differences among two groups of equipment. It was expected that paving and surfacing equipment may be operated more frequently in the summer months than other types of construction equipment. To test whether the responses for paving-related equipment were statistically different from all other equipment, we performed an analysis of variance (ANOVA) to compare the responses for these two groups of equipment. The ANOVA resulted in a significance or p-value less than 0.05, which indicates that samples were likely drawn from different populations with different mean values. This supported the development of an average paving and surfacing seasonal profile separate from all other construction. These profiles are shown in Table 2, as well as the NONROAD model seasonal profile.

Equipment Populations

To estimate equipment populations for the entire region, scaling factors were developed by SIC and SCC. These factors were calculated by dividing the number of pieces of owned equipment by the number of employees. An example calculation for diesel rollers in SIC 1771 follows.

Equation (1) $$SF = Eq_{SCC,\,SIC} \div Emp_{SIC}$$

where

$SF_{SCC,\,SIC}$	=	Scaling factor, for SCC/SIC combination
$Eq_{SCC,\,SIC}$	=	Equipment count from survey, by SCC and SIC; 8
Emp_{SIC}	=	Employment for surveyed respondents by SIC; 693

Resulting in:

Equation (2) $$SF_{SCC,\,SIC} = 8 \div 693 = 0.0115$$

State-level employment for SIC 1771, including surveyed and non-surveyed employees, was then multiplied by this scaling factor to yield the following estimate of State-level SCC-level equipment populations:

Equation (3) $Eq_{SCC,\ Total} = SF_{SCC,\ SIC} * Emp_{Total}$

where

Eq_{SCC}	=	State equipment count, by SCC
$SF_{SCC,\ SIC}$	=	Scaling factor for diesel rollers used in SIC 1771; 0.0115
Emp_{ST}	=	State employment for SIC 1771; 7,207

Resulting in:

Equation (4) $Eq_{SCC,\ Total} = 0.0115 * 7{,}207$ = 83 diesel rollers

Scaling factors developed from rental company equipment population data were also developed in a similar manner and applied to employment for the rental firms. Scaling factors were calculated for each SCC by dividing the number of pieces of leased equipment by the total number of employees. It should be noted that within the rental company SICs, especially SIC 7359 - *Equipment Rental and Leasing, Not Elsewhere Classified*, there was a high percentage of non-qualified respondents within the sample for these SIC classifications. This was determined based on the survey disposition report, which tracks and records the outcome of all telephone calls made during the survey. As such, Pechan made an adjustment to the employment data for the rental equipment SICs to account for this relatively higher percentage of non-eligibility. State-level employment for all Midwest RPO States was adjusted downward from 29 to 46 percent for SICs 5083, 7353, and 7359. To estimate total equipment in use, we added populations derived from scaling the owned equipment to populations derived from scaling the rental equipment.

Equipment populations are reported by horsepower ranges in NONROAD. The LADCO survey requested the average engine horsepower by SCC. We estimated a weighted average horsepower for each equipment type based on survey responses and then compared these to the NONROAD horsepower values, weighted by equipment populations. The average survey horsepower values were generally comparable to the NONROAD model. To be consistent with the NONROAD inputs, one would obtain equipment population estimates by SCC and horsepower. To use an SCC-level average horsepower value in the model, one would need to make assumptions about how to distribute the revised populations to the various horsepower bins. Because the average values were relatively comparable and the method to assign revised populations to the horsepower bins to reflect the new average would be arbitrary, we did not make adjustments to the horsepower distribution. These SCC-level populations were then incorporated into the NONROAD population input files by horsepower bin using NONROAD's distribution of engines by horsepower.

Table 3 presents the survey populations by equipment category (all fuels combined) for the Midwest RPO region, and compares these values to the NONROAD default populations. As noted in the table, we did not replace NONROAD defaults with results for off-highway tractors or other construction equipment. The estimated populations for these SCCs exceeded the national equipment populations, the number of responses for off-highway tractors was small, and what constitutes "other construction equipment" can be interpreted differently by respondents. Though not shown, variations in the differences do exist among the States, based on their relative employment for these SICs.

AGRICULTURAL EQUIPMENT

For the Agricultural sector, we focused on improving the NONROAD default spatial and temporal allocations. The NONROAD default spatial allocations are based on county-level total harvested crop acreage as reported in the *1992 Census of Agriculture*. Although the NONROAD model uses input files containing state-level agricultural equipment populations, these values are summations of the county-level estimates derived from allocating national equipment populations based on harvested acreage in each county. The NONROAD defaults for the Great Lakes/Midwest region, which covers all 8 states included in the scope of the agricultural equipment study, assume that 50 percent, 22 percent, 6 percent, and 22 percent of annual agricultural equipment activity occurs in the summer, fall, winter, and spring months, respectively. We developed improvements to both the spatial and temporal allocations from county and weekly diesel fuel consumption estimates developed in this effort.

Spatial Allocations

The spatial allocation factors compiled from the *Census of Agriculture's* harvested crop acreage data can not account for any crop- or state-specific differences in agricultural equipment use intensity (e.g., differences in use attributable to higher per acre productivity and/or higher non-till/conservation tillage rates in certain states). Therefore, we developed county-to-state allocation factors from agricultural sector diesel fuel consumption estimates. We estimated agricultural sector diesel consumption in each county by multiplying U.S. Department of Agriculture (USDA) estimates of diesel fuel use per planted acre by county-level planted crop acreage data[5,6]. The USDA reports diesel, gasoline, and liquified petroleum gasoline consumption estimates for major crops. As noted in Table 4, these estimates are provided as an overall average by crop, and, for major crop-producing states, by crop and state. Because diesel fuel consumption factors are more readily available and because diesel is the primary fuel used to operate self-propelled agricultural planting/harvesting equipment (e.g., the NONROAD model estimates that both nationally and in the states of interest, approximately 98 percent of total agricultural equipment fuel consumption is from diesel-fueled equipment), the focus of this effort was on developing diesel fuel consumption estimates. Although the USDA developed diesel consumption estimates from surveys of fuel use associated with all crop activities (i.e., pre-planting tillage, planting, cultivation, harvesting, hauling, and post-harvesting), the estimates are expressed on a number of acres planted basis.

Table 5 identifies the top 5 crops (based on planted acreage in 2002) for each of the eight states included in this study. Although hay and oats are two of the top five crops on a planted acre basis, the USDA does not report fuel consumption estimates for these crops. Based on consultation with USDA personnel, the diesel fuel consumption estimates for wheat were used for oats. For hay, an average fuel consumption factor was developed using equipment-specific diesel fuel consumption per acre estimates available from University of Minnesota and Iowa State University[7,8]. An example calculation based on equipment-specific diesel fuel consumption estimates is provided in the temporal allocation section below. Unlike other crops, the USDA does not report planted hay acreage. Although the USDA reports the number of acres of hay harvested, these values represent acres harvested for a single cutting. Hay is harvested 3-6 times per year depending on the length of the growing season. We assumed an average of 3 harvests per year due to the shorter growing seasons associated with many of the states included in this study.

Figure 2 presents the change in the percentage of each county's contribution to total agricultural activity between the NONROAD model defaults and the percentages developed from this study's diesel fuel consumption estimates. In this figure, a higher proportion of state activity will be allocated to counties in red using the diesel fuel consumption estimates than indicated by the NONROAD model defaults (with the darker red counties indicating the greatest increase in activity). Similarly, less state activity will be allocated to the counties in green (with darker green counties indicating the greatest decrease in activity).

Because the scope of this effort was limited to eight Midwest region states while the NONROAD model estimates county-level equipment populations by applying allocation factors to national equipment populations, LADCO will apply the county allocation factors developed in this effort to state equipment populations. There are two potential sources of state agricultural equipment populations: NONROAD model and *Census of Agriculture*. Because the NONROAD model state-level equipment population estimates are based on national estimates allocated using surrogate indicators that may not always correlate well with local equipment use, LADCO will review state-level agricultural equipment population estimates from the forthcoming *2002 Census of Agriculture* as a potential alternative. Although the *Census* estimates are based on a survey of farms in each state, and do not account for agricultural equipment use outside of the farm sector (e.g., by landscaping firms), it is believed that such use is minor relative to use within the farm sector.

Temporal Allocations

The following were the steps used to develop the temporal allocation factors by state:

1) Identify Production Operations By Crop;
2) Estimate Diesel Consumption By Operation;
3) Estimate Time-Frame for Operation;
4) Apportion Acres of Operation By Week;
5) Calculate Weekly Diesel Consumption;
   a) Estimate Diesel Consumption by Operation (multiply diesel consumption by state by crop [from spatial allocation] by the proportion of diesel consumption by operation);
   b) Estimate Diesel Consumption by Operation by Week (multiply diesel consumption by operation by the proportion of annual operation occurring in each week); and
   c) Estimate Diesel Consumption by State (sum across operations/crops within each state).

Tables 6 and 7 provide example calculations of the procedure used to develop weekly temporal allocation factors for corn production in Iowa in year 2002. For corn production, it was assumed that all four potential crop production operations (i.e., planting, cultivation, harvesting, and post-harvesting) are used. Table 6 shows the calculations performed to estimate the proportion of total diesel fuel consumption for each of these corn production operations. Based on an average of University of Minnesota and Iowa State University diesel fuel consumption per acre estimates for nine corn production machinery operations[7,8], we estimated the following break-down of diesel fuel consumption by corn production operation: Planting - 31.36%; Cultivation - 10.93%, Harvesting - 37.19%, and Post-Harvesting - 20.52%.

To estimate the time-frame for corn planting and harvesting operations in Iowa, and to estimate the acreage associated with these operations in each week, we compiled 2002 year planting and harvesting data from the USDA's Agricultural Statistics' web-site[9]. This publication reports the weekly cumulative percentage of the total 2002 year planted acreage and harvested acreage by crop and state. Each week's proportion of total planting and total harvesting of corn in Iowa was then calculated from these values. These proportions were then applied to the total acres of year 2002 planted corn in Iowa to estimate the number of acres of crops planted and harvested by week. Because temporal information is not available on cultivation/post-harvesting activities, we made the following simplifying assumptions:

1) All cultivation takes place between the last three weeks of the planting season and three weeks before the start of the harvesting season.
2) All post-harvesting activity takes place over the period that includes the last three weeks of the harvesting season and one week after the end of the harvesting season.
3) Cultivation and post-harvesting activities occur on an equal basis over each week in which these activities are assumed to occur.

Diesel fuel consumption by operation is then estimated using the USDA's diesel consumption per planted acre estimates that were used in the spatial allocation procedure (e.g., 4.6 gallons per acre for corn) and the percentage of fuel consumption associated with each production activity. These estimates were then allocated to each week in 2002 based on the estimated weekly number of acres associated with each crop's production activity (i.e., planting, cultivating, harvesting, and post-harvesting). The weekly diesel fuel consumption by operation values are then summed across production operations to yield total weekly diesel consumption. These weekly diesel consumption values for corn are then summed with weekly diesel consumption estimates for soybeans, wheat, hay, and oats (although included in the spatial allocation calculations, sugar beets were not included in the temporal allocation calculations because of a lack of information). These state-level weekly totals are then divided by each state's annual diesel fuel consumption to calculate the weekly percentage of 2002 year nonroad agricultural equipment activity by state. Because the NONROAD model does not currently support weekly temporal allocation factors, the weekly fuel consumption values were used to calculate monthly percentages, which the current model supports.

CONCLUSIONS

The construction equipment survey obtained equipment population and other activity data from targeted equipment users in the Midwest RPO. Because the survey established a statistical sample based on SIC and not equipment, some of the survey activity data were more appropriately analyzed and applied across all SCCs, or groups of SCCs. Adjustments to the weekly activity fractions, seasonal fractions, and annual hours of use were made to reflect the survey results. Most of the equipment populations resulting from the survey results were used to replace the NONROAD model defaults, but there were some exceptions, including off-highway tractors and other construction equipment.

Table 8 presents regional annual NO_x emissions by equipment category (all fuels combined) that reflect revisions made to default equipment populations and annual hours of use. The NO_x emissions resulting from the survey are compared to estimates obtained using NONROAD defaults. The category contributing to the largest regional increase in NO_x emissions is off-highway trucks. Since the number of data points used in calculating the scaling factors is relatively robust (over 50), there is not a strong basis to discount these estimates over other category estimates. It is important to note that the results of this study, though predicated on responses from actual equipment users and rental companies, are based on a relatively small sample of establishments/employment in the Midwest region. We surveyed 390 establishments representing approximately 3 percent of the total regional employment. Future surveys involving a larger sample size would assist in corroborating the results of this initial survey effort.

The agricultural equipment study results in a significant improvement in the ability to characterize nonroad agricultural equipment activity in the eight Midwest region states of interest. Table 9 displays the estimated proportion of diesel consumption by month for each major crop across the eight states included in this study. Note, for example, that unlike the other major crops, hay and oats are associated with a large proportion of annual activity in the summer months. Table 10 presents a comparison of the monthly allocations by state from this study with the NONROAD model default monthly allocations. Note, for example, the larger proportion of total activity in November and December in Wisconsin. A review of the USDA crop progress data indicates that the 5-year average planting and harvesting dates for corn and soybeans tend to be later than those for more southern states such as Illinois. In addition, 2002 was associated with later than average planting and harvesting dates, presumably due to weather conditions specific to that year. Although there are some differences in the allocations across states in the region, the proportion of annual activity that is allocated to the summer months is significantly lower than assumed by the NONROAD model defaults. It is important to note that the temporal data compiled in this study can also benefit other aspects of inventories (e.g., fugitive dust) in the states of interest.

There were several assumptions used in this study to develop temporal allocation factors. We expect that more representative assumptions for each crop and state may be available from contacts with state agricultural experts in the region. For example, it may be more appropriate to assume that a certain percentage of corn post-harvesting activity takes place in the spring rather than fall. Although further research would provide improvements to these assumptions, it is not anticipated that the refinements would have a significant impact on the major conclusion from this study that the NONROAD model over-allocates agricultural activity to the summer months in the Great Lakes/Midwest region states.

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Table 1. Comparison of weekly profiles.

Time Period	NONROAD model	LADCO survey
Monday	0.166667	0.181400
Tuesday	0.166667	0.181400
Wednesday	0.166667	0.181400
Thursday	0.166667	0.181400
Friday	0.166667	0.181400
Saturday	0.083333	0.046500
Sunday	0.083333	0.046500
Weekday Total*	0.833333	0.907000
Weekend Total**	0.166667	0.093000
Weekday/Weekend Fraction	2.0	3.9

*One Weekday multiplied by 5.

**One Weekend day multiplied by 2.

Table 2. Comparison of seasonal activity percentages.

Category	Winter	Spring	Summer	Fall
NONROAD - All Construction	10%	23%	43%	23%
Survey - Paving and Surfacing	12%	21%	38%	29%
Survey - All Other Construction	20%	19%	26%	36%

Table 3. 2002 Construction equipment populations for Midwest RPO.

Equipment Category	NONROAD Model Population	Survey Population	Difference
Bore/Drill Rigs	21,332	9,353	-11,979
Cement and Mortar Mixers	39,729	5,172	-34,557
Concrete/Industrial Saws	16,572	29,686	13,114
Cranes	4,522	3,540	-982
Crawler Tractor/Dozers	16,605	19,036	2,431
Crushing/Processing Equipment	2,544	4,184	1,640
Dumpers/Tenders	4,598	3,853	-745
Excavators	17,197	25,867	8,670
Graders	5,687	5,594	-93
Off-highway Tractors*	339	4,733	4,394
Off-highway Trucks	2,328	16,104	13,776
Other Construction Equipment*	2,193	32,452	30,260
Pavers	4,390	1,543	-2,847
Paving Equipment	19,263	3,736	-15,526
Plate Compactors	20,197	32,096	11,899
Rollers	13,074	9,608	-3,466
Rough Terrain Forklifts	16,296	9,160	-7,136
Rubber Tire Loaders	24,046	29,146	5,100
Scrapers	3,137	5,059	1,921
Signal Boards/Light Plants	7,632	3,796	-3,836
Skid Steer Loaders	71,993	30,089	-41,903
Surfacing Equipment	3,314	4,600	1,285
Tampers/Rammers	23,267	17,340	-5,927
Tractors/Loaders/Backhoes	52,689	38,270	-14,419
Trenchers	12,131	29,098	16,967
	405,073	**373,114**	**-31,959**

*The surveyed populations for these categories did not replace the NONROAD model defaults.

Table 4. Agricultural diesel fuel consumption factors by crop and state.

Commodity	State	Diesel Use (Gallons/Planted Acre)
Corn	ALL[1]	6.2
Corn	IA	4.6
Corn	IL	3.7
Corn	IN	4.6
Corn	MI	7.2
Corn	OH	4.3
Corn	WI	7.4
Hay[2]	ALL	4.6
Soybeans	ALL	4.5
Soybeans	IA	4.1
Soybeans	IL	3.7
Soybeans	IN	3.2
Soybeans	MI	4.4
Soybeans	OH	2.8
Soybeans	WI	4.5
Sugarbeets	ALL	17.9
Sugarbeets	MI	12.3
Sugarbeets	WI	31.5
Wheat All	ALL	4.4
Wheat All	IL	2
Wheat All	OH	2.3
Oats[3]	ALL	4.4
Oats[3]	IL	2
Oats[3]	OH	2.3

[1] ALL refers to all states that grow and harvest the crop specified.
[2] Hay estimates were computed from equipment-specific fuel consumption per acre estimates and assuming three harvests/year.
[3] Wheat values were assumed for oats per discussion with USDA.

Table 5. Top 5 crops planted in 2002 by state.

State	#1 Crop	#2 Crop	#3 Crop	#4 Crop	#5 Crop	Percent Of State Total Planted Acres[1]
IA	Corn	Soybeans	Hay	Oats	Wheat	100.0
IL	Corn	Soybeans	Hay	Wheat	Sorghum	99.7
IN	Soybeans	Corn	Hay	Wheat	Oats	100.0
MI	Corn	Soybeans	Hay	Wheat	Beans	92.1
MN	Corn	Soybeans	Hay	Wheat	Sugarbeets	93.5
MO	Soybeans	Hay	Corn	Wheat	Cotton	94.5
OH	Soybeans	Corn	Hay	Wheat	Oats	99.9
WI	Corn	Hay	Soybeans	Oats	Wheat	95.6

[1] Represents the proportion of total planted acreage in 2002 for the crops included in the temporal allocation procedure (i.e., corn, soybeans, hay, oats, wheat, and sugarbeets) relative to the total planted acreage in 2002 for all crops in the state.

Table 6. Estimation of diesel fuel use for corn operations.

#	Operation	Equipment	MN	IA	Average
1	Apply Fertilizer	Anhydrous Appl 130 MFWD	0.53	0.55	0.54
2	Offset Disc	12' 105 MFWD	0.83	0.85	0.84
3	Plant Corn	Row Crop Planter 60-130 MFWD	0.34	0.4	0.37
4	Rotary Hoe	21' 105 MFWD	0.18	0.2	0.19
5	Cultivate	15'-40' 60-200 MFWD	0.44	0.4	0.42
6	Combine Corn	Combine Corn Head 15-30' 220-275 HP	2.3	1.45	1.88
7	Haul Corn		0.2	0.2	0.20
8	Apply Herbicide	Boom Sprayer 50'	0.11	0.11	0.11
9	Chisel	Front Disc 16.3-21.3' 200 MFWD-310 4WD	0.97	1.1	1.04
		Planting (1-3)	1.70	1.80	1.75
		Cultivating (4-5)	0.62	0.60	0.61
		Harvesting (6-7)	2.50	1.65	2.08
		Post Harvesting (8-9)	1.08	1.21	1.15
		Total Fuel	**5.90**	**5.26**	**5.58**
		Planting	28.81%	34.22%	31.36%
		Cultivating	10.51%	11.41%	10.93%
		Harvesting	42.37%	31.37%	37.19%
		Post Harvesting	18.31%	23.00%	20.52%

Notes:

MN figures taken from University of MN Extension Service FO-6696: Farm Machinery Economic Costs for 2004
IA Figures taken from IA State University Extension PM 709: Fuel Required for Field Operations.
Hauling figures taken from PM 709 and applied to all states.

Table 7. Calculation of weekly corn production diesel fuel consumption estimates in Iowa, 2002

		Planting	Cultivating	Harvesting	Post Harvesting		State	StFips	Corn Planted	Gal of Diesel per Acre	Diesel Fuel
% of Total		31.36	10.93	37.19	20.52		IA	19	12,300,000	4.6	56,580,000
State	**Week Ending**	**Total Planted (%)**	**Total Harvested (%)**	**Weekly Progress Planted**	**Weekly Progress Harvested**	**Planted Acres**	**Cultivated Acres**	**Harvested Acres**	**Post Harvesting Acres**	**Diesel Fuel (gal)**	**% of Annual Allocation**
IA	Apr 14	1		1	0	123,000				177,446	0.3%
IA	Apr 21	12		11	0	1,353,000				1,951,909	3.4%
IA	Apr 28	33		21	0	2,583,000				3,726,371	6.6%
IA	May 5	53		20	0	2,460,000				3,548,925	6.3%
IA	May 12	86		33	0	4,059,000				5,855,726	10.3%
IA	May 19	94		8	0	984,000	878,571			1,861,375	3.3%
IA	May 26	98		4	0	492,000	878,571			1,151,590	2.0%
IA	Jun 2	100		2	0	246,000	878,571			796,697	1.4%
IA	Jun 9			0	0		878,571			441,805	0.8%
IA	Jun 16			0	0		878,571			441,805	0.8%
IA	Jun 23			0	0		878,571			441,805	0.8%
IA	Jun 30			0	0		878,571			441,805	0.8%
IA	Jul 7			0	0		878,571			441,805	0.8%
IA	Jul 14			0	0		878,571			441,805	0.8%
IA	Jul 21			0	0		878,571			441,805	0.8%
IA	Jul 28			0	0		878,571			441,805	0.8%
IA	Aug 4			0	0		878,571			441,805	0.8%
IA	Aug 11			0	0		878,571			441,805	0.8%
IA	Aug 18			0	0		878,571			441,805	0.8%
IA	Aug 25			0	0					0	0.0%
IA	Sep 1			0	0					0	0.0%
IA	Sep 8			0	0					0	0.0%
IA	Sep 15		4	0	4			492,000		841,602	1.5%
IA	Sep 22		6	0	2			246,000		420,801	0.7%
IA	Sep 29		10	0	4			492,000		841,602	1.5%
IA	Oct 6		13	0	3			369,000		631,202	1.1%
IA	Oct 13		21	0	8			984,000		1,683,204	3.0%
IA	Oct 20		41	0	20			2,460,000		4,208,011	7.4%
IA	Oct 27		61	0	20			2,460,000		4,208,011	7.4%
IA	Nov 3		76	0	15			1,845,000		3,156,008	5.6%
IA	Nov 10		89	0	13			1,599,000		2,735,207	4.8%
IA	Nov 17		96	0	7			861,000	3,075,000	4,375,317	7.7%
IA	Nov 24		99	0	3			369,000	3,075,000	3,533,715	6.2%
IA	Dec 1		100	0	1			123,000	3,075,000	3,112,914	5.5%
IA	Dec 8			0	0				3,075,000	2,902,513	5.1%
					Totals	**12,300,000**	**12,300,000**	**12,300,000**	**12,300,000**	**56,580,000**	**100.00%**

Note: Total Harvested percentage for December 1 was assumed (USDA does not report weekly crop progress data after 95 percent of total national crop has been planted/harvested)

Table 8. 2002 construction equipment NO_x emissions for Midwest RPO, tons per year.

Equipment Category	NONROAD Model Default Inputs	LADCO Survey Inputs	Difference
Bore/Drill Rigs	2,147	3,609	1,462
Cement & Mortar Mixers	137	11	-126
Concrete/Industrial Saws	304	1,233	929
Cranes	2,858	2,575	-283
Crawler Tractor/Dozers	20,271	26,819	6,548
Crushing/Proc. Equipment	623	1,987	1,365
Dumpers/Tenders	22	154	132
Excavators	12,671	22,119	9,448
Graders	4,371	4,917	546
Off-highway Tractors*	1,169	1,209	40
Off-highway Trucks	13,820	111,594	97,774
Other Construction Equipment*	1,912	1,935	23
Pavers	1,204	573	-631
Paving Equipment	342	350	8
Plate Compactors	72	106	34
Rollers	3,278	2,530	-748
Rough Terrain Forklifts	4,124	2,691	-1,433
Rubber Tire Loaders	19,156	24,133	4,978
Scrapers	4,684	8,662	3,978
Signal Boards/Light Plants	291	155	-136
Skid Steer Loaders	5,605	2,671	-2,933
Surfacing Equipment	97	250	154
Tampers/Rammers	15	22	6
Tractors/Loaders/Backhoes	10,821	7,723	-3,098
Trenchers	1,448	2,096	647
	111,444	**230,126**	**118,682**

*NO_x emissions reported for these categories in both columns are based on NONROAD model defaults.

Table 9. Monthly proportion of fuel consumption by crop for states of interest.

CROP	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Corn	0.0	0.0	0.0	6.6	17.1	12.6	3.5	2.8	6.2	17.3	24.1	9.7
Hay	0.0	0.0	0.0	1.0	14.6	26.0	24.2	12.5	16.0	5.6	0.0	0.0
Oats	0.0	0.0	4.7	13.9	8.2	1.9	30.0	30.6	10.7	0.0	0.0	0.0
Soybeans	0.0	0.0	0.0	0.4	12.9	22.9	7.7	7.7	7.3	34.3	6.3	0.5
Wheat	0.0	0.0	0.0	0.4	3.3	13.9	37.0	13.2	9.4	20.8	1.9	0.2

Table 10. Comparison of monthly allocations from NONROAD model and this study.

STATE	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
IA	0.0	0.0	0.0	6.4	23.2	8.9	6.0	4.9	5.8	27.1	14.5	3.1
IL	0.0	0.0	0.0	4.1	10.9	20.9	6.6	5.5	6.9	30.1	9.6	5.4
IN	0.0	0.0	0.0	0.7	9.3	25.4	7.4	5.3	5.2	26.6	14.0	6.2
MI	0.0	0.0	0.0	1.2	15.8	16.5	9.4	6.9	6.0	22.5	15.2	6.4
MN	0.0	0.0	0.0	3.9	23.1	8.0	5.9	8.5	10.2	19.5	15.2	5.7
MO	0.0	0.0	0.1	8.3	9.0	22.5	9.1	6.4	13.2	18.2	12.3	0.9
OH	0.0	0.0	0.0	1.0	9.1	24.0	10.8	6.2	5.5	24.6	13.4	5.3
WI	0.0	0.0	0.0	2.1	19.7	12.6	7.0	6.9	4.7	14.7	22.4	10.0
Average	**0.0**	**0.0**	**0.0**	**3.5**	**15.0**	**17.3**	**7.8**	**6.3**	**7.2**	**22.9**	**14.6**	**5.4**
NONROAD	**2**	**2**	**7.3**	**7.3**	**7.3**	**16.7**	**16.7**	**16.7**	**7.3**	**7.3**	**7.3**	**2**

Figure 1. Comparison of weekday and weekend day diurnal profiles.

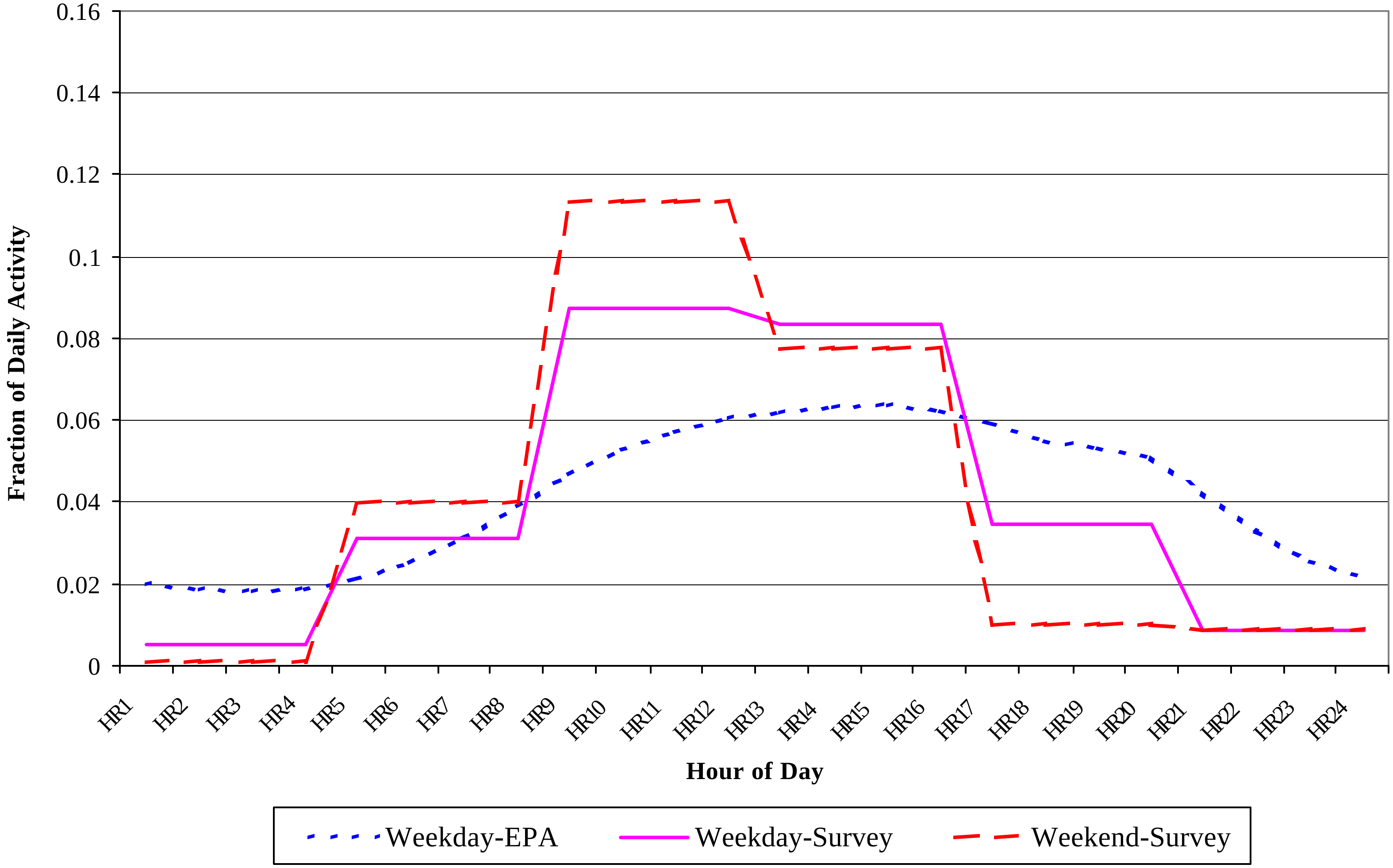
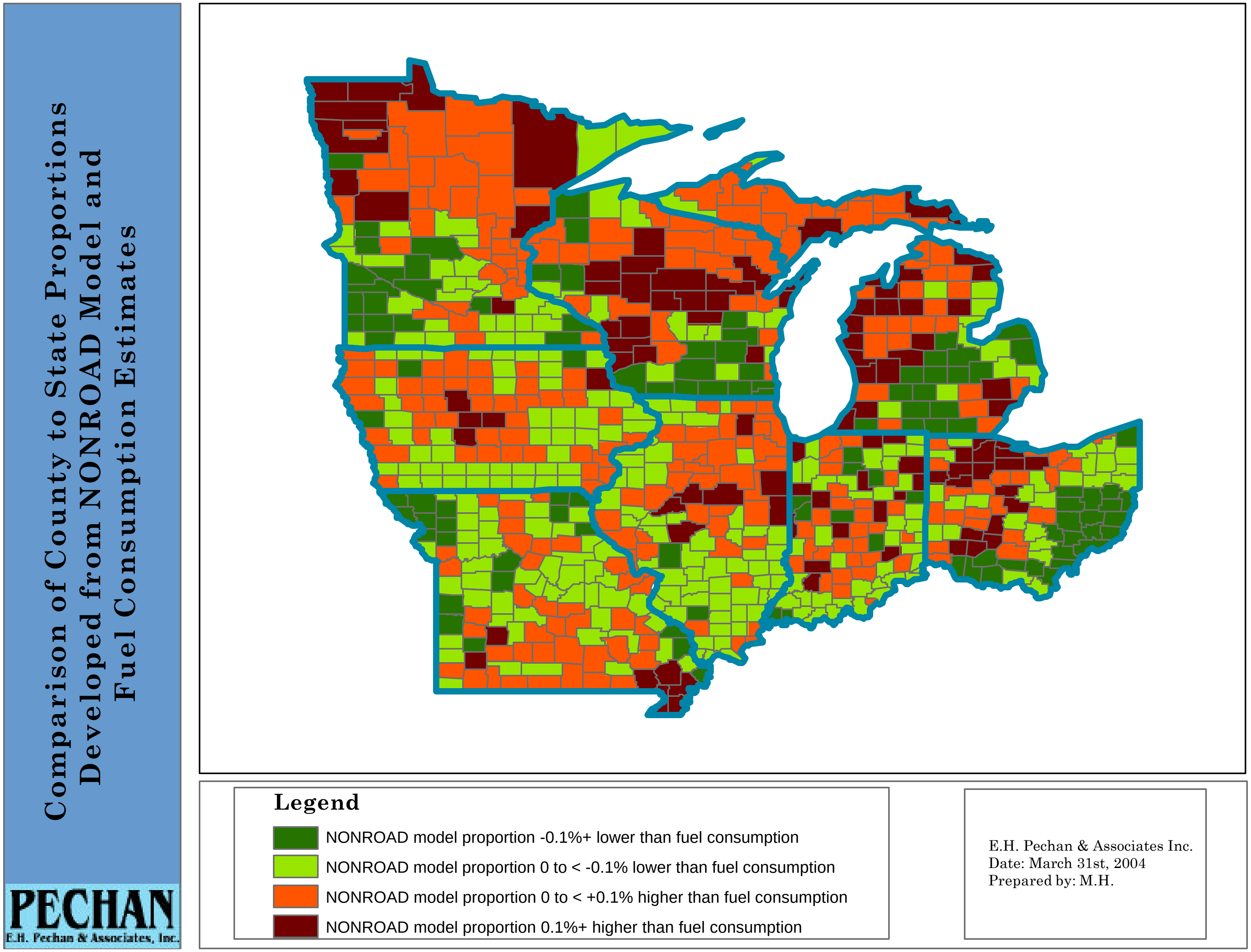


Figure 2. Comparison of county proportions of state activity (fuel consumption-based estimates minus NONROAD model estimates)



KEYWORDS
Agricultural Equipment
Construction Equipment
Emission Inventories
Nonroad Sources
Spatial Allocation
Temporal Allocation