

Estimating Indirect Land Use Change Emissions from Biofuels



Comments by Clean Air Task Force to California Air Resources Board

On the ILUC emissions estimate discussed in ARB's presentation

"iLUC Analysis for the Low Carbon Fuel Standard (Update)" (March 11, 2014)

May 19, 2014

Overview

The Clean Air Task Force (CATF) is a non-profit environmental organization that works to protect the earth's atmosphere by improving air quality and reducing global climate change through scientific research, public advocacy, technological innovation, and private sector collaboration. CATF is pleased to submit the following comments to the California Air Resources Board concerning ARB's review of the indirect land use change (ILUC) emissions associated with biofuels and how those emissions are accounted for within the state's Low Carbon Fuel Standard (LCFS).

Although research into the effect that biofuels have on climate change is marked by uncertainty and controversy, it is increasingly evident that the production and consumption of some types of biofuels are undermining efforts to reduce greenhouse gas (GHG) emissions. As compared to other policies being used to promote biofuels—most notably, the federal Renewable Fuel Standard—the LCFS represents a significantly better platform for evaluating net GHG emissions and rewarding the fuels with the lowest carbon intensities. CATF is therefore committed to helping ARB ensure that the best and most current research is used to inform its assessments of the carbon intensities of different fuels, especially biofuels.

These comments highlight three factors that ARB should take into account as it evaluates the ILUC emissions estimate used to calculate the carbon intensity of biofuels in the LCFS context:

- Studies that supposedly demonstrate a trend toward lower ILUC emissions estimates—including versions of the Global Trade Analysis Project (GTAP) model that ARB relies upon to implement the LCFS—typically ignore how water scarcity constraints will impact crop expansion. A recent analysis that takes water scarcity into account finds that earlier studies "likely underestimated induced land use emissions due to ethanol production by more than one quarter."
- GTAP's inability to differentiate commercial forest from non-commercial forests means that the model wrongly assumes that markets respond to the conversion of both land types in the same way.
- The yield improvement assumptions in GTAP overlook important differences among crops and growing regions, they fail to incorporate new research on future corn yields

in the Midwest United States, and they do not adequately address the climate impact associated with the increased use of nitrogen-based fertilizers to sustain yield growth.

Each of these factors separately suggest that the GTAP model is currently under-counting ILUC emissions. Taken together, they indicate that a reduction to the ILUC emissions estimate discussed in ARB's March 11, 2014, presentation, "iLUC Analysis for the Low Carbon Fuel Standard (Update),"¹ would not be appropriate. CATF therefore urges ARB to keep the ILUC estimate at its current level until ARB can more fully account for the issues raised here and at the March workshop.

[I] The "Trend" Toward Lower ILUC Emission Estimates Is Illusory

In California (as in Washington DC), the ethanol industry has aggressively promoted the idea that ILUC emissions estimates for corn ethanol are steadily trending downward as new lifecycle analyses are published. The industry places particularly high value on particular publications by Purdue researchers Wally Tyner and Farzad Taheripour that point toward relatively low estimates of ILUC emissions, e.g., a 2012 paper that reduces the estimated land requirements for US ethanol production by 25%.² The cited studies have important shortcomings, however—a problem that is exemplified by the way in which the studies have ignored real-world constraints on the amount of water available for new agriculture.

In fact, more recent work by Taheripour is intended to correct this oversight. In a 2013 study he co-authored by Thomas Hertel and Jing Liu, two other researchers from Purdue, he writes: "[I]n contrast to the recent trend in such studies, incorporating explicit modeling of irrigation, and associated constraints, *significantly raises the land-based emissions associated with biofuel expansion.*"³

Taheripour *et al.* (2013) opens with two key points. First, water availability is essential to understanding the land use impact of biofuel expansion, especially with water availability projected to decrease over the next two decades.

[T]he question of whether expansion of global cropland cover involves irrigated or rainfed lands make a significant difference in terms of how much new land will be required to provide the additional production called for in the presence of biofuels ... [I]f the expansion of irrigated land is constrained, either due to insufficient water or due to insufficient pumping capacity, then it is likely that more cropland area will be required to meet the additional global demand induced by ethanol production.⁴

The authors cite recent studies that predict large water deficits, including an analysis by McKinsey which estimates that by 2030 water demand will exceed water supply by 40%. "In summary," Taheripour *et al.* write, "it appears that water for agricultural irrigation will become much more expensive in the future – no doubt spurring considerable efficiency gains, but also raising the cost of production and therefore limiting the amount of land on which irrigated crops can be economically grown."⁵

Second, refining land use change models to account for real-world constraints on water availability reveals a greater likelihood that biofuels expansion will drive displaced agricultural

production into areas that are rainfed. “These regions tend to be more carbon rich and therefore exhibit higher ILUC emission factors,” write Taheripour *et al.* “Therefore, earlier models which ignore the role of irrigation in crop expansion tend to underestimate the ILUC emissions due to biofuel expansion.”⁶

One such model is GTAP-BIO, which Taheripour and Tyner used in the earlier 2012 study to assess the land use impacts of the 2015 ethanol mandate in the US Renewable Fuel Standard.⁷ (GTAP-BIO, of course, is used to generate the emissions estimates for biofuels that ARB relies upon to implement the LCFS.) The enhancements that Taheripour *et al.* make to GTAP in the 2013 study allow the model to recognize water scarcity constraints and distinguish between rain-fed and irrigated land. Figures 3 and 6 from Taheripour *et al.* (2013) illustrate the extent to which the intensity of global land use change can differ when models are programmed to distinguish between irrigated crops and rainfed crops, and when constraints on water availability are introduced:

Fig. 3 from Taheripour *et al.* (2013)

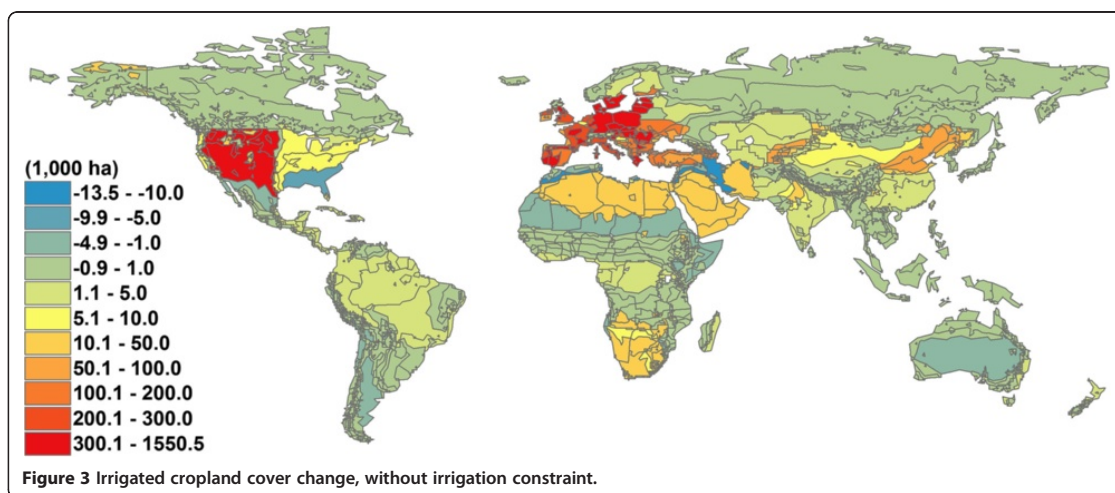
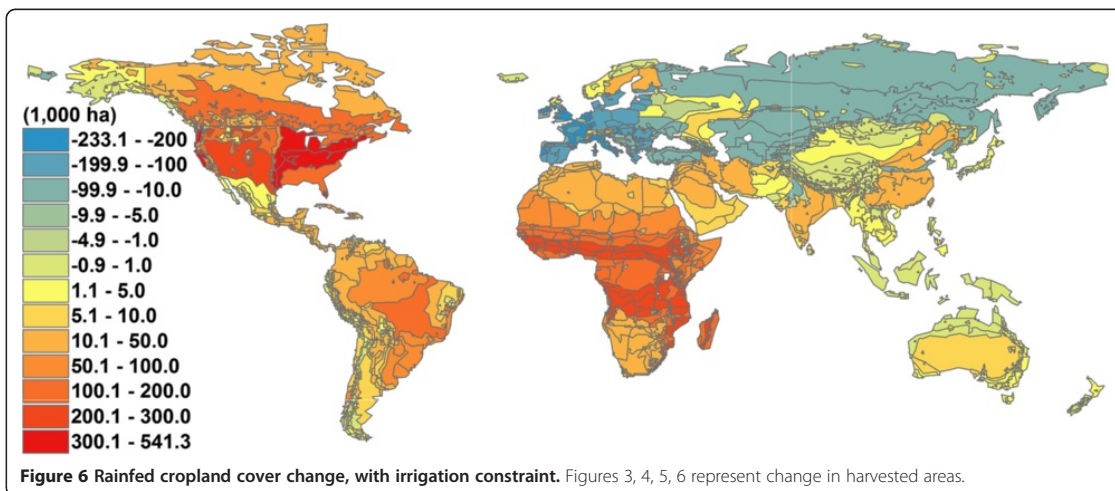


Fig. 6 from Taheripour *et al.* (2013)



By sensitizing the model to these factors, the 2013 study finds that ILUC emissions are likely to be substantially higher than prior estimates:

[I]ncreasing US ethanol production from its 2001 level to 56.78 billion liters causes about 35.6 g CO₂e/MJ emissions if there is no irrigation constraint across the world. Factoring in the physical limitations on irrigation expansion increases the land-based emissions to 45.4 g CO₂e/MJ. This means that the physical water scarcity adds 27.5% to the emissions due to land use changes induced by ethanol expansion. As shown in Table 5 [excerpted below], the constrained case also generates 27.5% more emissions compared to the case wherein we ignore irrigation altogether. This means that earlier studies, which failed to distinguish rainfed from irrigated lands, likely underestimated induced land use emissions due to ethanol production by more than one quarter.⁸

Table 5 from Taheripour et al. (2013)

Table 5 Land use emissions due to US ethanol production

Simulations	Ethanol production (billion liters)	Annualized ILUC emissions	
		(g CO ₂ e/MJ)	Deviation from no-irrigation (%)
Unconstrained	50.08	35.6	-0.05
No-irrigation	50.08	35.6	0.0
Constrained	50.08	45.4	27.5

An additional point worth noting in this context is that both of the values cited in the 2013 study for corn ethanol—35.6 and 45.4 g CO₂e/MJ—are higher than the central values that ARB presented at the March 11 workshop (30.0 and 23.2 g CO₂e/MJ).⁹

In its March 2014 presentation, ARB staff notified the Board that the current version of GTAP fails to differentiate between the irrigated and rain-fed land and assumes that the water availability (or, rather, the unavailability of water) does not affect the model's estimates concerning the conversion of new land for crop production. Staff flagged two of the problems connected with this assumption—water is not an unlimited resource, and it cost money to irrigate newly converted cropland—and pointed out that, “Crop expansion and crop switching decisions will require availability of water resource and may change model predictions.”¹⁰ According to the presentation, staff plans to collect data on water availability, productivity differences, and land elasticity, and integrate those data into a revised GTAP model within the next few months.¹¹

This effort to incorporate water-related restrictions on biofuel demand-driven cropland expansion is likely to materially affect ARB's estimate of the net GHG emissions associated with the LCFS. The 2013 study by Taheripour et al. indicates that ignoring the role of irrigation in cropland expansion “introduces systematic biases in the measurement of the size and pattern of global land use changes and therefore the land use emissions due to production of biofuels.”¹²

We therefore encourage ARB to ensure that water constraints are accounted for in the lifecycle emissions analyses used to assess the treatment of biofuels within the LCFS.

[II] GTAP's Treatment of Forest Conversion Artificially Suppresses ILUC Emissions

Currently GTAP represents three land-use classes: forestry, pasture, and cropland. These are economic uses of land, however, not land-cover types. That is, GTAP does not represent forests generally; it represents economically productive timberland. As a result, the model assumes that any conversion of forestry land causes a reduction in timber supply, which in turn creates upward pressure on timber prices. This assumption has two effects that are likely to produce lower projected ILUC emissions.

First, the opportunity cost of converting commercial forestry land is greater than the opportunity cost of converting forestland that is not in economic use. The assumption within GTAP that all forestland is commercially managed therefore exaggerates the economic limits on non-commercial forest conversion. Consequently, the model likely projects less overall forest conversion than it would if it differentiated between commercial and non-commercial forests and made both types available for conversion.

Second, once commercial forestland is converted, there is an *afforestation* response elsewhere that makes up some portion of the lost timber supply. GTAP fails to appreciate that the conversion of non-commercial forestland would not produce a similar afforestation response.

Notably, other models used to estimate land-use change emissions—including IFPRI's MIRAGE, MIT's EPPA, and PNNL's GCAM—allow for the conversion of non-commercial forestland.

ARB staff referenced these concerns in their presentation for the March 2014 workshop, explaining that GTAP's inability to differentiate between forest categories "creates unrealistic deficit from wood products in the forestry sector."¹³ A temporary fix involving adjustments to the Land Transformation Elasticity (ETL) values was proposed, with a completion target of April 2014.¹⁴ It is not clear from ARB's website whether this fix has been executed or how the adjustment impacts the ILUC estimate. CATF cannot specifically comment on the proposed fix until we have reviewed the results of the ETL adjustment, but we are encouraged that ARB has identified this problem and is committed to addressing it. We urge ARB to ensure that its ILUC determination is based on land use modeling that effectively differentiates between commercial and non-commercial forestland.

[III] Aspects of GTAP's Treatment of Yield Problematically Affect ILUC Analysis

Several of the ways in which GTAP treats future crop yields are suppressing the model's ILUC emission projections. These include the model's assumption that price-induced yield improvements for all crops in all regions will match the improvement rate projected for Midwestern US corn, the model's current failure to accommodate new research suggesting that future corn yield improvements in the Midwest US could decelerate, and model's ongoing failure to adequately address the climate impact associated with the increased use of nitrogen-based fertilizers to sustain yield growth.

[A] GTAP's Handling of Yield Price Elasticity Suppresses ILUC Estimates

Yield price elasticity is perhaps the most controversial parameter in the GTAP model. GTAP utilizes a single number which determines how much yields—of all crops, in all regions— increase in response to price increases. Most arguments about price-induced yield improvements have focused on the “correct” value for this parameter, while failing to recognize that no such parameter exists in the real world: no single value can properly capture the substantial variability across crop types, climatic conditions, and economic conditions.

In practice, nearly all of the discussion about this parameter is informed by studies of one crop grown in one region—i.e., corn grown in the US Corn Belt. There is little reason to expect that the yield effects measured for corn in the Midwest, a growing region characterized by fertile soil and readily available capital, to be representative of the effect that minor price increases have on, say, rice yield in developing regions.

When setting a range of values to consider for yield price elasticity within GTAP, ARB must treat this parameter as representing the *average* yield elasticity for all crops, in all regions, which is likely to be lower than what has been achieved by corn growers in the United States. The high values suggested for the US corn should be treated as the maximum obtainable. If GTAP assumed (appropriately) that not all crops grown around the world will achieve the same level of yield price elasticity as US corn, estimated ILUC emissions would likely increase.

[B] GTAP Does Not Incorporate New Research on Future Corn Yields

The assumptions made in GTAP about future crop yields do not yet take into account important new research by David Lobell and others on the impact that future drought conditions will have on Midwest US corn yields over the next 50 years. According to the study—Lobell *et al.*, “Greater Sensitivity to Drought Accompanies Maize Yield Increase in the U.S. Midwest,” *SCIENCE* (May 2, 2014)—a greater incidence of midsummer drought conditions will slow the steady improvement in corn yields that farmers have historically achieved by increasing their cropping density. Assuming that finding is corroborated, it should be incorporated into GTAP's assumptions about future yield improvement.

According to the study, a handful of factors have allowed farmers to increase the density at which they plant corn and soy—e.g., no-till agricultural, higher ambient CO₂ concentrations, and genetic enhancements. Increased density has contributed to yield improvements, but it also “can be detrimental under drought conditions because of excessive stress exposure for individual plants.”¹⁵ The authors examined how corn and soy respond to various environmental stresses to determine “the net effect of recent genetic, agronomic, and environmental changes on drought sensitivity.” They find that corn yields are particularly sensitive to increases in daytime vapor pressure deficit (VPD), “a widely used measure of atmospheric water demand that depends on air temperature and humidity.” VPD increases appear to be especially impactful when they occur 2-3 months after a corn crop is sowed.¹⁶ As Figure 4(B) from Lobell *et al.* shows, VDP during that timeframe (July, approximately) is expected to climb significantly over the next forty years:

Fig. 4 from Lobell et al. (2014)

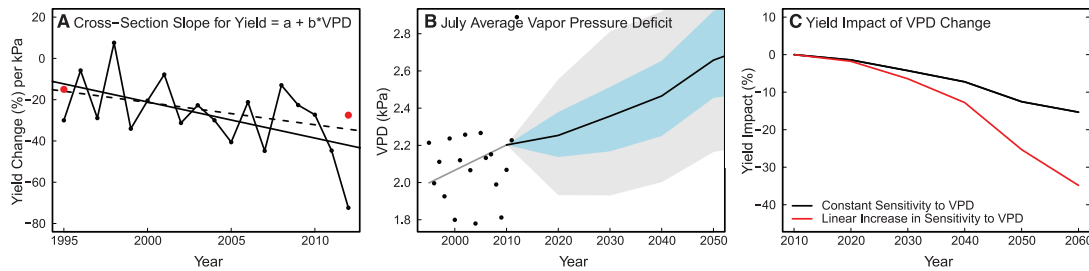


Fig. 4. Changes in vapor pressure deficit and its impacts. (A) Estimates of maize yield sensitivity to VPD 61 to 90 days after sowing from a cross-sectional regression for each year in the study period, along with best-fit trend lines with (solid) or without (dashed) including 2012 for computing the trend. Red dots indicate sensitivity estimates from APSIM simulations with sowing densities corresponding to the start and end of the study period. (B) Average July VPD in the study region for historical and projected periods. Dots show individual year observations, gray line shows linear trend for 1995 to 2012, black line shows mean VPD projected using 29 climate models, blue shading indicates 25th to 75th percentile of model projections, and gray shading indicates 5th to 95th percentiles. (C) Estimated impact of mean VPD projections on average maize yields using either constant yield sensitivity of -27.5% per kPa or a linear increase in sensitivity at the historical rate of 7% per kPa per decade.

The study concludes that if corn-growing regions continue to experience hotter and drier Julys, current projections for corn yield improvements are unlikely to be met:

One implication is that climate change effects may be more severe than predicted by models that assume current crop genetics and management. Climate model projections indicate that July VPD for this region will become more severe, with an expected increase in average VPD of roughly 20% over the next 50 years (Fig. 4B), driven both by higher temperatures and reduced relative humidity. At current VPD sensitivity, these VPD trends would reduce yields by about 15% over the next 50 years. If maize yields continue to become increasingly sensitive to VPD, then yield losses from VPD trends could be as much as 30% (Fig. 4C).¹⁷

In addition to casting doubt on long-term yield projections for corn (the feedstock used to produce more than 80% of the biofuel consumed in the United States in 2013), Lobell et al.'s findings support the point made above that ARB should not use a yield price elasticity value for corn as a proxy for the elasticity of other crops' yields. Lobell et al. demonstrate that there are important physical constraints on corn yields that farmers may not be able to overcome through the commitment of additional resources. Accordingly, the study suggests that GTAP's yield price elasticity value for corn may not be appropriate for corn, much less for other crops.

Consequently, ARB should ensure that the new work by Lobell et al. informs future yield projections and the effect those projections have on ILUC estimates.

[C] ARB's Modeling Framework Undercounts N₂O Emissions

The modeling framework used by ARB assumes that yields for a wide range of crops will climb in response to increased demand for biofuel feedstocks, but it does not adequately account for the extra emissions associated with the farming techniques that will be utilized to achieve those higher yields. The likely result of ARB's approach is that ILUC emissions are undercounted.

Adding fertilizer, for example, results in additional emissions of nitrous oxide (N₂O), a potent greenhouse gas. ARB's modeling framework currently accounts only for the N₂O emissions that result from fertilization of the feedstock crops used to produce biofuels. This approach

ignores the additional use of fertilizer for other crops, even when that additional usage is tied to an overall rise in crop prices brought about by new demand for energy crops. Under the existing modeling framework, therefore, the benefit of price-induced yield increases are counted, while the cost to climate of achieving those increases is not. If ARB accounts for both sides of the equation—i.e., improved yields *and* higher N₂O emissions—as it should, estimated ILUC emissions are likely to increase.

In the March 2014 presentation, ARB staff acknowledged that both crop intensification and crop extensification associated with increased biofuel demand could result in additional N₂O emissions.¹⁸ We urge ARB to fully account for these emissions when estimating ILUC emissions.

[D] GTAP's Treatment of Marginal Crop Yields Increases Uncertainty

One of the recent changes to GTAP that contributed to the proposed reduction in ILUC emissions relates to how the model represents yield on newly converted cropland. GTAP previously relied on a single value of 0.66 to represent the relative productivity of newly converted land,¹⁹ until Taheripour et al. (2012) used the Terrestrial Ecosystem Model (TEM) to estimate relative yields on a regional basis.²⁰ The shift to regionalized estimates is an improvement conceptually, but the implementation of this change creates additional uncertainty—leaving in doubt whether this change produces a better representation of reality.

To implement this change, Taheripour et al. estimated the average net primary productivity (NPP) of a single crop—based on corn grown in the US Corn Belt—for land not currently used for crop production in each Region-AEZ combination, and the average NPP of land currently in crop production in that Region-AEZ.²¹ The ratio of these NPP values—truncated to a maximum value of 1.0²²—is used as a proxy for the relative yield of newly converted cropland.²³ This approach implicitly incorporates the following assumptions:

- *That Iowa's 1996 corn season is an appropriate proxy for all crops grown around the world.* (TEM is parameterized using data for corn grown in 1996 in Iowa, one of the world's most productive corn producing regions.)
- *That NPP is a good proxy for yield, and the difference in yield between these two land-use classes is best represented as a constant ratio (A/B) rather than, say, a constant difference (A-B).*
- *That TEM's estimate of NPP is correct.* (Pan et al. (1996) performed sensitivity analysis on the TEM model (version 4.0), showing that estimated NPP is sensitive to different assumptions about soil texture, temperature, precipitation, and radiation—all of which may vary within a given Region-AEZ.²⁴)
- *That the average NPP of all land not in crop production is a good approximation of NPP on the land actually converted.* (This assumption holds true only when land selection is random or there is little variability of NPP across land in the Region-AEZ. Neither of these are claimed to be the case in the study.)
- *That truncating some of the NPP ratios to 1.0 produces a valid estimate of marginal yield.* (Taheripour et al. make this adjustment in their 2012 study as a way of recognizing the unlikelihood that yields are better on land not being used for production. It remains unclear, however, why this adjustment is necessary if the basic method of computing

NPP and using the ratio is valid. In other words, if the method produces values that are believed to be unrealistically high in some cases, what basis is there to believe that the other values produced by TEM (i.e., those <1.0) are not likewise too high?)

In principle, regionalized estimates of marginal yield can produce more accurate model results. Whether this is true in practice, however, depends on how the regionalized values are determined. It is unclear whether the present implementation brings GTAP results closer to reality or further from it.

Conclusion

CATF believes that California's LCFS can play a globally important role in identifying and promoting fuels that can meaningfully reduce GHG emissions from transportation. We therefore appreciate the opportunity to help ARB ensure that the best and most current research is used to assess the carbon intensities of different fuels, particularly biofuels.

In order to develop a more reliable ILUC estimate, CATF urges ARB should ensure that its model fully appreciates the extent to which water scarcity will constrain future crop expansion, effectively differentiates commercial forest from non-commercial forests, and utilizes the most comprehensive and up-to-date data on yield improvements.

Sincerely,

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ENDNOTES

¹ John Courtis, Anil Prabhu, Farshid Mojaver, and Kamran Adili. iLUC Analysis for the Low Carbon Fuel Standard (Update), California Air Resources Board, (March 11, 2014) (hereafter “March 2014 Staff Presentation”).

² Farzad Taheripour, Quinlai Zhuang, Wallace E. Tyner, and Xioliang Lu. Biofuels, Cropland Expansion, and the Extensive Margin. ENERGY, SUSTAINABILITY AND SOCIETY 2012 (hereafter “Taheripour et al. (2012)”).

³ Farzad Taheripour, Thomas W. Hertel and Jing Liu. The Role of Irrigation in Determining the Global Land Use Impacts of Biofuels. ENERGY, SUSTAINABILITY AND SOCIETY 2013. 3 (emphasis added) (hereafter “Taheripour et al. (2013)”).

⁴ *Id.* at 1-2.

⁵ *Id.* at 2.

⁶ *Id.* at 2.

⁷ Taheripour et al. (2012) at 6.

⁸ Taheripour et al. (2013) at 9.

⁹ March 2014 Staff Presentation at 61.

¹⁰ March 2014 Staff Presentation at 42.

¹¹ *Id.* at 43.

¹² Taheripour et al. (2013) at 1.

¹³ *Id.* at 45.

¹⁴ *Id.* at 45.

¹⁵ David B. Lobell et al. Greater Sensitivity to Drought Accompanies Maize Yield Increase in the U.S. Midwest. SCIENCE 2014. 516.

¹⁶ *Id.* at 517.

¹⁷ *Id.* at 519.

¹⁸ March 2014 Staff Presentation at 47-48.

¹⁹ See Thomas W. Hertel et al. Global Land Use and Greenhouse Gas Emissions Impacts of US Maize Ethanol: Estimating Market-Mediated Responses. BIOSCIENCE 2010.

²⁰ See Taheripour et al. (2012).

²¹ *Id.* at 3.

²² *Id.* at 8.

²³ *Id.* at 3.

²⁴ Yude Pan, et al. The Importance of Climate and Soils for Estimates of Net Primary Production: A Sensitivity Analysis with the Terrestrial Ecosystem Model. GLOBAL CHANGE BIOLOGY 1996.