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A novel approach to optimizing a global farmland portfolio

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SUMMARY

Nuveen Natural Capital believes that a globally diversified farmland strategy has the potential to improve the efficiency of investor's portfolios. By diversifying the crop mix and geographies, investors can protect against external physical and market risk factors such as weather, crop price volatility and government intervention and regulation. But this leads to a question: what is the optimal way to construct a globally diversified farmland portfolio?

In this paper, we examine Nuveen Natural Capital's approach to portfolio construction, outlining how we apply risk and optimization modeling to build risk-return efficient portfolios of farmland investments. We also demonstrate how an investor's approach to currency risk has a material impact on regional allocations. Finally, we demonstrate that there are material allocation differences in optimal portfolios depending on whether an investor's investment objective is to maximize cash yield, total return or both.

INTRODUCTION

Modern portfolio theory is often applied to improve economic decision-making when selecting a traditional investment portfolio. Applying this theory requires information on both the expected return of an investment and the covariance of returns between investments. Despite the prevalence of portfolio optimization in traditional asset classes, its application in the construction of global farmland portfolios, and across real assets more broadly, has not been widespread due to the absence of reliable historical performance data.

Farmland is still considered a nascent asset class by most institutional investors. One of the major challenges in effectively analyzing the sector relates to obtaining sufficient and accurate historical performance data for the various investment opportunities within the asset class.

Due to the dearth of agricultural performance data and benchmarks that are available globally, it has been difficult to apply portfolio optimization in the context of local farmland portfolios, let alone those with global scope. While datasets are

available across certain regions, the information can be inconsistent and can often misrepresent the actualized returns of institutional grade farmland investments.

To overcome this challenge, Nuveen Natural Capital developed a novel approach to generate the required inputs for a portfolio optimization model, incorporating currency approaches and portfolio objective preferences into the modeling framework.

PORTFOLIO CONSTRUCTION

Utilizing a quantitative approach to assess risk and return provides us with a competitive tool to evaluate the global set of investment opportunities, highlighting tradeoffs between risk and return. The modeling framework supports strategy development, the re-profiling of existing farmland portfolios to improve risk-return efficiency, the evaluation of individual investment opportunities and the optimal construction of new portfolios.

Given the global set of investment opportunities (IOs) included in the investable farmland universe, the portfolio optimization model requires the following inputs:

(1) Expected return for each IO;

(2) Return variance for each IO; and

(3) Covariance across IOs.

The novel optimization approach incorporates both a top-down and bottom-up perspective. The top-down approach defines the investable universe, or the set of investment opportunities to be included in the optimization. In the top-down approach, we also estimate the risk of each investment opportunity.

Expected returns for each investment opportunity are derived from the bottom-up approach as they reflect currently achievable and forecast go-forward rates of return, largely informed by our on-the-ground investment teams. The bottom-up approach also defines what is actually achievable due to market constraints such as capital availability, liquidity and scale of each strategy, and the complexities of operating real assets in the U.S. and foreign jurisdictions.

Our unique approach combines both top-down theoretical elements and bottom-up real-time returns and constraints, creating a high-fidelity approach that accurately models risk and returns.

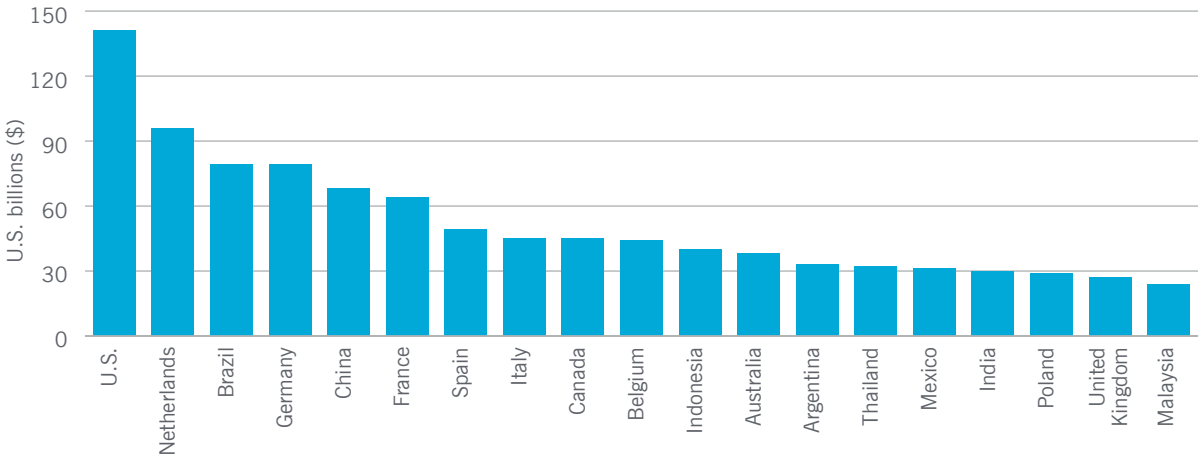
TOP-DOWN

Defining the investable universe

The first step in developing our high-fidelity model is to define the investable universe. Global farmland portfolios often contain a mix of unique investments, each characterized by crop type, geography and management strategy.

To better understand the opportunity set for farmland investing, Exhibit 1 below shows countries that have sizeable agricultural output measured by export value. Though this is a starting point for reviewing the investable universe, this data does not capture domestic markets and not all countries or opportunities are suitable for institutional investors. The institutional investment universe must consider institutional investors' risk tolerance and objectives. Consequently, investment geographies that are challenged by uncertain political, economic or social situations, or without sufficient scale, are considered as unsuitable investment opportunities. Target investment opportunities must offer a relatively secure business environment, as well as ownership and crop types which have the necessary scale for institutional farm management. For example, whilst China and Argentina (shown in Exhibit 1 below) exist within the farmland universe, current country risk factors such as political uncertainty make them unsuitable for institutional investment. As such, they are excluded from the institutionally investable universe.

Exhibit 1: Top 20 agricultural exporting countries by value (2017)



Data source: UNFAO

Institutionally investable opportunities (IOs) are identified by geography, crop type and operating strategy. Investments with robust fundamentals and strong growth prospects are included as IOs based on their:

1. **Country risk:** suitability for institutional investment
2. **Comparative advantage in production**
3. **Ability to scale:** liquidity at large scale
4. **Desirable operational characteristics:** immediate cash generation, operational value enhancement opportunities

In total, we identified 49 unique IO's across geographies and crop types, including 34 distinct row crop opportunities and 15 distinct permanent crop opportunities (global horticulture and global viticulture). The majority of permanent crop opportunities are operated. In the case of operated and leased out permanent crop assets income return predominates, as underlying land value appreciated is offset by depreciation of biological assets, trellis and irrigation infrastructure. Exhibit 2 summarizes the IOs currently in scope for portfolio optimization.

Exhibit 2: Summary of investment opportunities

Region & crop type	Leased	Operated
U.S. row crops	13	0
Australia row crops	5	0
Brazil row crops	2	0
European row crops	2	0
Global horticulture	7	10
Global viticulture	5	5
Total	**34**	**15**

Data source: Nuveen, December 31, 2019

Each IO has unique fundamentals, including drivers of supply and demand, production windows and sources of production. Therefore, the correlation between investment opportunities is usually low, a factor that makes agricultural investing unique. It is worth noting that the investable universe is not static and is periodically updated as a result of many factors (e.g., consumer preferences, country risk, and new investment research).

Exhibit 3 below highlights the limited correlation between investment opportunities.

Exhibit 3: Sample correlation matrix of investment opportunities

	Illinois row – leased	Mississippi row – leased	Australia row – leased	Brazil row – leased	Poland row – leased	Romania row – leased	U.S. almonds – operated	U.S. pistachios – operated	U.S. cabernet sauvignon– operated
Illinois row – leased	1.00	0.80	0.04	-0.25	0.75	0.57	0.18	0.18	0.32
Mississippi row – leased		1.00	0.00	-0.36	0.72	0.53	0.38	0.18	0.30
Australia row – leased			1.00	0.57	0.02	0.06	0.26	-0.17	-0.21
Brazil row – leased				1.00	-0.33	-0.20	-0.11	-0.29	0.18
Poland row – leased					1.00	0.34	-0.02	0.14	0.29
Romania row – leased						1.00	0.39	0.07	-0.18
U.S. almonds – operated							1.00	0.28	-0.12
U.S. pistachios – operated								1.00	0.73
U.S. cabernet sauvignon – operated									1.00

Data source: UNFAO, USDA, ABARES, Agroconsult, 1981-2019

Estimating risk (variance and covariance matrix)

As mentioned previously, the biggest challenge to the application of portfolio optimization in a global farmland portfolio is the lack of reliable performance information. Portfolio optimization in traditional asset classes typically uses historical returns to estimate a variance-covariance matrix. In this case, a lack of historical performance data for the asset class (or securities) does not preclude portfolio optimization. Instead, we rely on other performance measurements to approximate historical investment outcome of the asset class, thereby allowing us to estimate the risk (variance-covariance matrix) of farmland IOs.

The novel approach developed at Nuveen Natural Capital analyzes farm-level revenues to estimate risk in farmland investing. We use the year-over-year change to farm-level revenues to estimate the variance-covariance matrix. Annual farm-level revenues are modelled using crop-level revenues from historical yield and price data. For IOs that involve more than one crop, IO-level revenue changes are estimated by weighting the crop-level revenue change by the area harvested (or in some cases planted). To maximize the number of data points included in the analysis, we adopt bootstrapping approach across various data sources to construct the data set. We source crop-level data from publicly available data sources such as the USDA and UNFAO. Where needed, we supplement public data with private data sourced from consultants or internal proprietary data.

Applying the above methodology, a set of historical farm-level revenues for each IO is constructed. This data is used to calculate the variance-covariance matrix required for portfolio optimization.

Exhibit 4: Sample standard deviation of revenues of investment opportunities

Country/Region	Management strategy	Standard deviation
Illinois row	Lease	8%
Mississippi row	Lease	13%
Poland row	Lease	13%
Romania row	Lease	16%
Brazil row	Lease	20%
U.S. almonds	Operate	22%
U.S. cabernet sauvignon	Operate	23%
Australia row	Lease	25%
U.S. pistachios	Operate	56%

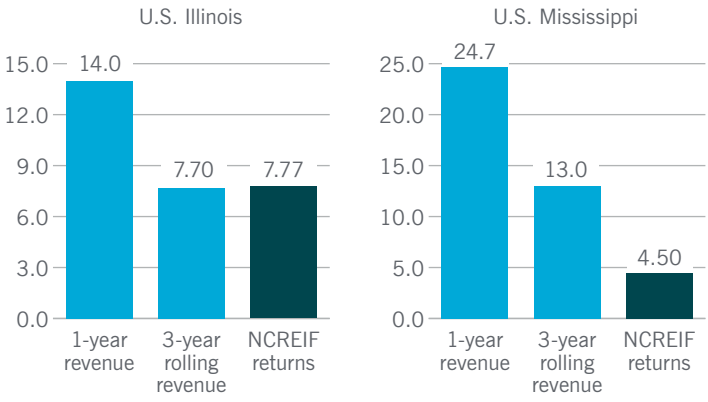
Data source: UNFAO, USDA, ABARES, Agroconsult, 1981-2019

Simplifying assumptions

Key simplifying assumptions require discussion. The first assumption is that farmland margins and cap rates are constant. Any estimate of the risk in farmland investing needs to account for risks to operating income and land values. If farm-level margins are constant then operating income will have the same volatility as farmland revenue. Additionally, if cap rates (discount factor of future expected cash flows to arrive at the net present value of land value) are constant then land values will also have the same volatility as farmland revenue. Therefore, risks to farmland revenue should be sufficient to approximate risks to both income, land value changes and investment returns in farmland.

Secondly, estimating the risk to farm leases must be addressed. Risks to lease structures are estimated by smoothing year-over-year revenue changes across three years. We determined this smoothing period by analyzing the volatility of comparable leased farmland returns in the NCREIF index as shown in Exhibit 5 below.[1]

Exhibit 5: Comparison of standard deviation of revenues (1-year and 3-year) vs NCREIF returns



Data source: USDA, NCREIF, as at December 31, 2019. **Past performance is no guarantee of future returns.** It is not possible to invest in an index.

Lastly, the approach does not account for specific risks associated with development properties. We can assume that the price paid for greenfield property will be discounted by the time and development risk required to achieve a fully producing property, such that the risk-return of the two are the same. Hence, for portfolio optimization purposes, we can assume that all horticulture and viticulture properties are mature and producing.

BOTTOM-UP

Nuveen Natural Capital's global presence enables a unique understanding of each of the IOs country risk, comparative production advantage, ability to scale and operational characteristics. This local knowledge provides us with a competitive advantage to create global portfolios with performance metrics that accurately reflect investor expectations.

Understanding this nuance forms the basis of our bottom-up approach. This informs the top-down optimization with parameter estimates and constraints that increase the fidelity of the model. Having investment staff on the ground allows us to leverage local expertise pertaining to specific operating strategies, capital deployment potential and opportunities to generate alpha through land development.

Estimating expected returns

Expected returns reflect current market environments and the level of returns local investment teams expect to generate for each IO. Though macro factors such as government policy and interest rates will have a significant effect on an IO, the primary source of expected returns is the economics of crop production. These economics are region and district specific, and provided by our local investment teams.

Applying constraints

Based on considerations such as capital availability, liquidity and operational complexity, constraints can be applied to limit the exposure to certain IO's. Our local investment teams inform these constraints.

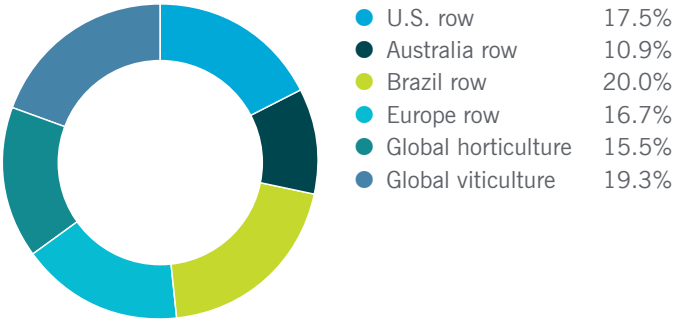
RESULTS

Optimized portfolio

Given the definition of the investable universe and the specific estimates of the mean returns and variance-covariance matrix of returns, the optimization model maximizes expected return at every level of risk to produce an efficient frontier. Throughout this section, we focus our discussion of results on the Sharpe-ratio-maximizing, optimal portfolio on the efficient frontier.

We begin by specifying an objective function that maximizes total return. Solving for the model, we identify the optimal portfolio and the weights assigned to each IO that maximize total returns (as shown in exhibit 6)[2]. As can be seen, allocation to U.S., Brazilian and European row crop opportunities are similar at around 20%. However, we see a divergence with the Australian row crop allocation. Given Australia's strong correlation with both European and U.S. row crops but with higher estimated risk, its respective allocation is lower. The high weighting to Brazilian row crops is attributed to its relatively high total return as well its negative correlation with all other IOs in the portfolio. Similarly, horticulture and viticulture IOs have low correlations with row crop IOs giving them 15% and 19% allocations, respectively.

Exhibit 6: Portfolio optimization results



Data Source: Nuveen, December 31, 2019

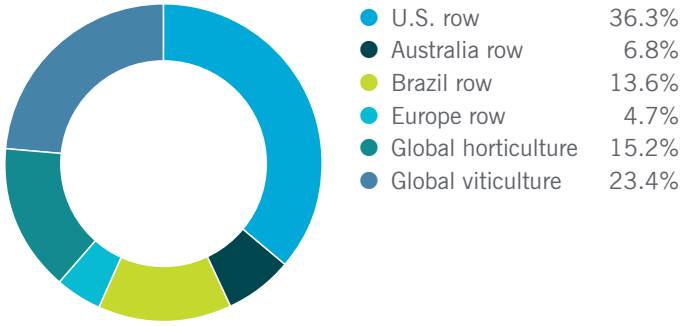
Accounting for currency risk

Portfolio optimization for a global portfolio would not be complete if we did not account for currency risk. In addition to developing a novel methodology to estimate risk in farmland investments, we have also incorporated various approaches to account for currency risk. These approaches include:

1. **Local Currency Approach:** Expected returns and covariance matrix inputs denominated in local currency.
2. **Hedge Approach:** Adjust IO expected return by hedging costs, but keep the covariance matrix the same as the local currency approach.
3. **Fund Denomination Approach:** Incorporate currency risk related to the underlying investments by converting covariance matrix inputs into fund denomination but keep expected returns as is.

These approaches yield different asset allocation outcomes, and are dynamic across time as currency volatility and hedging costs fluctuate. For illustration, again maximizing total return, we show the optimal portfolio but with the covariance matrix including currency risks against the U.S. Dollar (i.e., Fund Denomination Approach).

Exhibit 7: Portfolio optimization results with currency risk



Data source: Nuveen, December 31, 2019

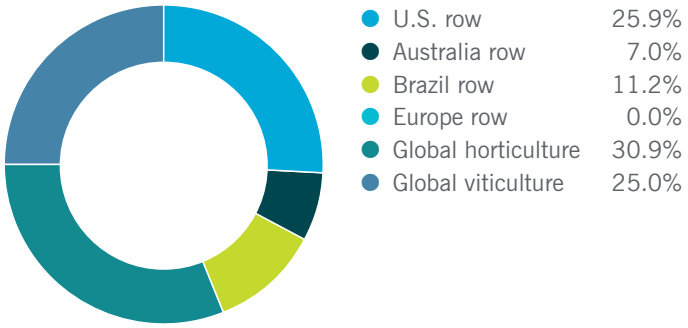
Overlaying the currency risk onto each IO has a material impact on the respective risk adjusted returns. In this example, the portfolio is optimized for a U.S. dollar-denominated fund. As such, U.S.-based investments are favorably weighted because they do not experience currency volatility. Again, we see the benefit of Brazilian sugar IO's negative correlation with all other investment opportunities, but the allocation is not as high as in the local currency case (Exhibit 6). To fund the difference in the increased allocation to U.S. Row, the largest impacted group of IOs is in European Row Crops, which, after accounting for currency risks offer less attractive risk adjusted returns compared to the local currency case. Australian row crops also receive a lower allocation.

Global horticulture and viticulture continue to have a sizeable allocation at 15% and 23%, respectively. This is attributed to a number of factors. First, many of the IOs in the global horticulture and viticulture group are based in the U.S.. Therefore, their risk adjusted returns were not impacted negatively by including currency risks. Secondly, even for IOs outside the U.S., the impact to allocation was limited due to their low correlation with all other investment opportunities. This lines up well with our intuitive understanding of these IOs and their limited exposure to currency risks given the nature of their return profile. Since the majority of their return is generated through annual cash yields rather than appreciation, the effectiveness of the natural hedge should be higher than non-U.S. row crop opportunities. Hence, they continue to have large allocations.[3]

Specification of the optimization model

The last feature of the portfolio optimization is the flexibility in how we define the objective function. Through a numerical solution method, optimal portfolio weights for each IO are selected in a way that maximizes the value of the objective function. Therefore, the set of optimal portfolio weights depends critically on how the objective is defined. Investors may prefer to construct a portfolio that maximizes a certain objective such as total return or annual income return, Nuveen Natural Capital's portfolio optimization process analyzes total return and annual income return both separately and jointly. Exhibit 8 describes the optimal portfolio to maximize annual income return and following the Fund Denomination Approach.

Exhibit 8: Portfolio optimization for annual income return with currency risks included



Data source: Nuveen, December 31, 2019

By comparing optimal portfolios using this alternative objective, we can see the effect of the portfolio being optimized for annual income return, as opposed to total returns seen previously in Exhibit 6. The movement of weightings is attributed to horticulture and viticulture's return profile being driven by annual income return, thus giving them a significantly higher allocation compared to row crops.

CONCLUSION

Farmland investing is still considered a nascent asset class by most institutional investors. Risk-return characteristics of portfolios are difficult to model, often leading to missed opportunities and a misunderstanding of return profiles.

Nuveen Natural Capital believes that a globally diversified farmland strategy has the potential to improve the efficiency of investor's portfolios. Our approach to portfolio construction utilizes a top-down and bottom-up optimization centered on creating risk-return efficient portfolios of high-performing farmland investments.

This unique modeling approach allows us to better understand the risk-return characteristics of the asset class as potential investments are evaluated. Two points of differentiation have enabled this achievement. Firstly, a lack of available data has been addressed by constructing proprietary datasets to accurately represent real-time risk-return scenarios. Secondly, our global farmland operations deliver the direct experience needed to model such an asset base.

Recognizing that some investors have a desire to invest in one geography, for example the U.S. or Australia, the same optimization approach can be applied with a narrower set of IOs, limited to the target country to establish the most desirable asset mix for that particular location.

Portfolio optimization employing this unique combination of robust top-down risk modeling and real-time bottom-up expected returns and constraints creates a real-world, high-fidelity model allowing investors to define their objectives and construct optimal farmland portfolios to achieve them.

For more information, please visit our website, nuveen.com/naturalcapital

Sources:

1 As shown the three-year smoothing works well for certain IOs such as U.S. Illinois but does not fully replicate volatility in other IOs such as U.S. Mississippi. However, it is worth noting that NCREIF returns for less invested regions such as U.S. Mississippi are not fully representative of the region and it is our belief that the risks in the index are understated.

2 It is important to note that the objective of the optimization shown here is for total returns and currency risk is intentionally not factored into the analysis (return and volatility are all recorded in local terms).

3 Farmland's natural hedge describes the negative correlation between the local currency revenue and asset value of the farm against currency movements. Consider a farm that grows crops that are sold in the global markets and priced in U.S. dollars. When the local currency weakens, the same volume of sales (in production) generates higher local currency revenues to the farm. Because asset values reflect future cash flows from owning and operating the farm, farmland value should also be higher in local currency.

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