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A study of agronomical practices for cultivation of selected plants for better yield

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ABSTRACT

Recent gains in crop yield may be primarily attributed to many factors, the most important of which are advancements in breeding and agronomy, as well as modifications to the spatial and temporal organization of crop production within agricultural systems. It is a widely held belief that one of the key variables that leads to higher productivity is the interaction that takes place between breeding and agronomy. For instance, dwarfing genes in cereals resulted to a physiological improvement in the grain/stem partitioning of dry matter, which had direct ramifications for yield. This improvement allowed for a greater proportion of grain to stem dry matter. When compared to previous, taller cultivars, these genes made it possible to apply larger rates of nitrogen fertilizer while simultaneously minimizing the danger of lodging. This was made possible by the combination of the two factors. It is vital to highlight that grass herbicides were necessary in order to take advantage of the benefits afforded by short-stature grains in automated production systems. This is something that should not be overlooked.

Keywords: agronomical, practices, cultivation, plants, physiological

INTRODUCTION

Improvements in breeding and agronomy, as well as alterations to the geographical and temporal organization of crop production within agricultural systems, are the primary contributors to recent increases in crop output. It is generally accepted that one of the primary factors that contributes to increased productivity is the interaction that occurs between breeding and agronomy. For example, dwarfing genes in cereals led to a physiological improvement in the grain/stem partitioning of dry matter, which had direct consequences for yield. These genes also made it possible to apply higher rates of nitrogen fertilizer while reducing the risk of lodging in comparison to older, taller cultivars. It is important to note that grass herbicides were essential in order to take advantage of the advantages that short-stature grains offered in mechanized production systems. As shown in Figure 1, issues related to politics, economics, the environment, and infrastructure may either promote or inhibit the development and implementation of technologies that increase productivity. Despite the significance they have, the discussion of these elements is not within the purview of this article. In a similar vein, we do not discuss policies that are intended to address yield disparities (Sumberg, 2012).

Determination of the factors that contribute to the differences in yield levels.

It has been established that there is a need for a sustainable improvement in agricultural production aimed at food security in a context of increasing pressure on natural resources (Cassman 2012; Connor and Mnguez 2012). This need has been established after an exhaustive analysis of the challenges that face global agriculture. According to the Food and Agriculture Organization of the United Nations (2011), out of a total land area of 13,000 Mha, arable land and permanent crops account for 12%, permanent meadows and pastures account for 26%, and forests account for 30%; however, 32% of this land is unsuitable for agriculture. An analysis that takes into consideration how suitable the remaining land is for farming as well as other potential uses for the land arrives at the conclusion that the increase of cropping land between now and 2050 is likely to be minimal. Globally, 15% of arable land is irrigated, which accounts for 42% of all crop production at the present time; 7100 km3 of water are consumed annually to produce food on a global scale, whereas feeding the world's population of approximately 9 billion people by 2050 would require an additional 2100 km3 year of water consumption (Sumberg 2012; Rockstrom et al. 2012).

Management choices to close the gaps whenever it is possible to do so.

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Although there is a growing awareness of the significance of investing in research and development in agriculture, there is a limited amount of financing available, and it is imperative that this funding be used more effectively (Sumberg 2012; Connor and Mnguez 2012; Hall et al. 2013). In this scenario, the typical and sometimes substantial difference between the actual yield and the achievable yield is an important aim. To make headway in this direction, we need: 1. Definitions and techniques to measure and model yield at different levels (actual, attainable, potential) and different scales in space (field, farm, region, global) and time. 2. Realistic solutions are required to close yield gaps in both small and large scale cropping systems around the world. 3. Realistic solutions are required to close yield gaps in both small and large scale cropping systems around the world. 4. Realistic solutions are required to close yield gaps in both small and large scale crop (short, long term).

Adoption policies that encourage the use of technologies that close gaps.

In this light, the purpose of this article is to conduct a review of the methodologies for yield gap analysis, and to make use of case examples to explain the various techniques. In section 2, we discuss the development of yield in order to provide light on the historical shifts that have occurred in the definition of this word; this

leads to the definitions of yield used in this paper. Section 3 highlights the importance of explicit definitions of spatial and temporal scales in yield gap analysis, and discusses different data sources and their reliability. Desirable attributes of models in yield gap studies are discussed, including aspects of model structure, complexity, calibration, validation and input requirements. Section 4 is the core of this publication. It presents methods spanning a broad range of scales, complexities, input requirements and associated errors. Case studies include irrigated and rainfed crops in diverse cropping systems, from subsistence agriculture to high-input systems in North and South America, Africa, Europe, Asia and Oceania. Section 5 presents a summary and recommendations of methods for yield benchmarking and gap analysis.

The university developed agro techniques, which are a package of practices, for the cultivation of medicinal plants (bach, muskdana, ashwagandha, Isabgol, sarpgandha, kalmegh, curcuma and safed musli) and aromatic plants (mentha, lemongrass, palmarossa, vetiver, german chameli, guggul, and eucalyptus). In order to facilitate the multiplication of

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seeds and other planting materials, the university established a nursery. There are around one hundred different species up for grabs at the nursery's gift shop.

OBJECTIVE

1. To study on the agronomical practices for cultivation of selected plants for better yield
2. To study on the Adoption policies that encourage the use of technologies that close gaps.

REVIEW LITERATURE

Donald 1981, This change in definition of yield had a dramatic impact on selective pressures, shifting from the aggressive high-yielding plant (seeds per seed sown) to the less competitive "communal plant" capable of producing more yield per unit area. This shift occurred as a result of the evolution of the definition of yield. Evans (1993) proposed the next measure of yield, yield per hectare per year, in which the time dimension is incorporated explicitly. When comparing systems with different levels of cropping intensity, i.e. the number of crops produced year, this metric is very crucial to take into consideration (Egli 2008; Cassman and Pingali 1995).

Cassman and Pingali (1995) noted that the "green revolution" in rice had as much to do with increasing cropping intensity as it did with higher harvest index and yield potential of semi-dwarf cultivars. This was one of the factors that contributed to the "green revolution." As a result, the first modern rice cultivar, IR-8, reached maturity much more quickly than the traditional rice land races it had replaced (often by as much as 30–45 days), which allowed for double rice cropping on irrigated land, which is now the predominant land use in rice-growing regions of South and Southeast Asia.

Cassman and Pingali (1995), Farahani et al. (1998), Caviglia et al. (2004), and Sadras and Roget (2004) all found evidence of an increase in cropping intensity in various parts of the globe. This requires a transition to many crops being grown each year in locations with temperatures that are favorable and an adequate supply of water. This is true not just in the tropics but also in more temperate regions such as Argentina's Pampas, where wheat and soybean double cropping is the most common kind of agricultural practice.

Connor and Mnguez 2012, This is because the yield of individual crops does not take into account the additional costs of land, time, labor, and water associated with organic nutrients. Comparisons of this nature that are to have any meaning must center on the gerogia natasi (2019) The common bean, also known as Phaseolus vulgaris L., is the most important legume grown for human consumption around the globe. It is also a significant source of protein, minerals, antioxidants, and bioactive substances. Because of this crop's ability to fix nitrogen, it has a lower need for the use of synthetic nitrogen fertilizer, which helps to improve both output and quality. It is possible to optimize the fertilization, yield, and quality of common bean by the use of a number of additional agronomic measures such as irrigation, the use of rhizobia, the sowing density, and so on.

RESEARCH METHODOLOGY

Quantification of yield gaps is possible at a variety of temporal and spatial dimensions (Hall et al. 2013). As a result, the precision and accuracy of the fundamental data for yield gap analysis need to be improved. taken into consideration in respect to the geographical and temporal scale of the goal. Yield gaps have been measured on a spatial scale at the levels of field (for example, French and Schultz 1984b), region (for example, Casanova et al.1999), national or mega-environment (for example, Caldiz et al. 2002), and internationally (for example, French and Schultz 1984b) (Licker et al. 2008). The aim of site-specific management is on minimizing the variation in yield that occurs within individual fields (Cassman 1999). However, there has been no effort made to take into account the variance that exists within the field in the yield gap study.

DATA ANALYSIS

The identification of restrictions, trade-offs, and potential for improvement may be achieved via the analysis of yield levels that differ from one another. When it comes to increasing agricultural output, closing the exploitable yield gap is of the utmost importance from a practical standpoint. Utilizing a few different case studies, we will now discuss the many sorts of procedures that are used in the process of yield benchmarking and gap analysis. The methodologies include a wide spectrum of sizes, complexity, input requirements, and faults that are connected with them. We categorized these techniques into four general categories.

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HIGH-YIELDING FIELDS, EXPERIMENTAL STATIONS AND GROWERS C

The yields in a farmer's fields can be compared to a variety of references, such as the yields of the best-performing crops in neighboring fields, the yields in experimental stations, or the yields in growers contests under conditions that are comparable in terms of the soil, topography, weather, and biotic factors.

Sunflower In Rainfed Systems Of Argentina

In Argentina, Hall et al. (2013) compared the yield of rain-fed sunflowers at many scales, from the provincial to the national level. On the basis of the recommendations of several experts, the 2.25 million acre sunflower producing area was divided into eight distinct zones. The reported yields of those districts within each area that contributed the most to the overall regional production were used in the process of estimating the mean real yield on an annual basis. As a means of arriving at an estimate of the achievable yields for each year and location combination, the mean yields from yield comparison studies were used. These achievable yields are comparable to those that are water-limited (Section 2.2). The number of years for which data were appropriate ranged from 5 to 9 according to area. The difference between the actual yield and the feasible yield was large in every location. The gap ranged from 20 to 77% of mean actual yields, which, in turn, varied from 1.52 to 2.25 t ha-1 depending on the region. The difference between the actual yield and the achievable yield was 0.75 t ha-1 on a national scale, which is equal to 41% of the average national yield of 1.85 t ha-1.

Maize In Sub-Saharan Africa

In their study on experimental stations and agricultural fields, Sileshi et al. (2010) compared the real maize yield that was attained with inorganic and organic nutrient inputs with the control, which received no input. The comparison also included yield gaps with inorganic and organic fertilizers, namely in situ green manure from sunhemp (Crotalaria spp.), velvetbean (Mucuna spp.), sesbania (Sesbania spp.), tephrosia (Tephrosia spp.), and gliricidia (Gliricidia sepium) on varied site circumstances. There was a matching grain yield from maize cultivated continuously without any external nutrient input (control) for each input that was tested at a particular location or during a certain season; this meant that there was a pair of means for each of the inputs (treatment and control).

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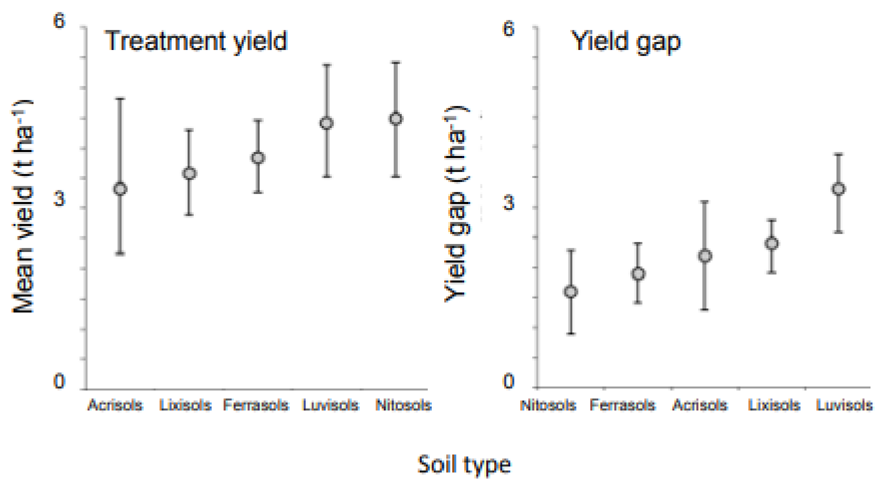
Table 4.1 provides a summary of the number of nations that were analyzed, the number of studies that were conducted, the extracted pairs of means, and the robust parameter estimates of yield gaps for each treatment. An ad hoc gap was defined as the difference in grain yield between maize grown using a given nutrient input and the control under a specific study condition. This analysis did not apply the hierarchy of yields that is typically used for gap analysis Instead, an ad hoc gap was defined as the difference in grain yield.

Table 4. 1 Basic Statistics And Robust Parameter Estimates (Winsorized Means And Coefficients Of Variation) Of Maize Grain Yield (T Ha-1) From Various Soil Fertility Management Inputs.

	Control	Fertiliser	Sunhemp	Velvetbean	Sesbania	Tephrosia	Gliricidia
Number of countries	12	13	11	12	7	9	5
Number of studies	110	71	39	45	42	28	14
Pairs of means#	473	346	214	242	262	177	114
Estimated mean	1.4	3.9	3.3	2.8	2.9	2.0	3.3
95% confidence band	1.3-1.4	3.7-4.1	3.0-3.6	2.6-3.1	2.6-3.1	1.6-2.2	3.0-3.6
CV (%)	69.3	46.3	54.4	59.4	67.2	67.3	43.0



Source: Sileshi et al. (2010).

Fig. 4. 1 Variation In Maize Mean Yield With Fertiliser And Yield Gap On Various Soil Types In Sub-Saharan Africa. Vertical Bars Indicate 95 Percent Confidence Bands.

In spite of the fact that maize has the genetic capacity to produce up to 10 tons per hectare, the actual yields have seldom been more than 8 tons per hectare. With the prescribed rate of fertilizer, the likelihood of yielding more than 8 t ha-1 was less than 3%, and the yields were

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less than 5 t ha-1 in 75% of the instances, regardless of the inputs. When compared to the control without any fertilizer as well as the organic nitrogen treatment, the inorganic nitrogen treatment resulted in a higher yield and a lower coefficient of variation. However, yield improvements on the fields farmed by farmers were smaller and more varied than those seen at research stations. It is possible that these differences are the result of factors that, in general, cannot be transferred, such as the environmental conditions and management practices that are utilized at research stations. At these locations, greater attention is paid to the sowing dates, spacing, weeding, fertilizer doses, and pest control than it is in the fields of farmers.

Detailed statistical analysis also showed a variance in yield gaps with elevation, mean annual precipitation, and soil type, including clay content. These factors were all taken into consideration. Despite the fact that yields on Nitosols were typically greater than those on other soil types when using the prescribed amount of inorganic fertilizer, yield improvements over the control were the lowest (Figure 4.2). The'saturated soil fertility' effect can be responsible for the reduced gain on Nitosols.

The degree of variation in yield gaps, as represented by the 95% confidence bands, was greatest for Acrisols and Nitosols, while it was at its lowest for Lixisols. It's possible that the susceptibility of acrisols to degradation is to blame for their wide range of variability (Stocking, 2003). The findings of the analysis suggested, on the whole, that the organic inputs from the legumes might have significant effects on soils that are more susceptible and less robust.

Grain Legumes In India

In India, soybean, peanut, chickpea, and pigeonpea yield gaps were analyzed by Bathia et al. (2006) in a regional-level study. They examined the differences in real yield across experimental stations, the best farms, and whole districts. The fact that the mean yield, as well as the maximum and lowest yields, were calculated for each yield category and then utilized for yield gap estimates is an intriguing component of this study (Figure 4.2). The information that can be obtained from each of these several measures of yield gap is unique from one another, and this differentiation is especially significant when it comes to determining the possible factors that are responsible for the gaps. Nutrient availability, for example, is a lot more probable source of gaps in maximum yield, which is the yield reached

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in more favorable (wetter) seasons, than it is to produce gaps when yield is minimal. This is because maximum yield is the yield achieved in seasons with more favorable conditions. It is essential for the management of risk to make an effort to determine particular yield gaps in harsh seasons in order to make it possible to capitalize on the advantages of favorable seasons.

Wheat-Maize Double Crop In The Hebei Plain Of India

The majority of benchmarking studies concentrate on individual crops. The research conducted by Liang et al. (2011) is one of the rare cases that focus on double harvests. The findings of the research were derived from a survey that was conducted on 362 farms across six counties in the Hebei Plain. In this region, the wheat–maize double crop is the single most significant component of the system. The greatest yield, the average yield, and the lowest yield were all calculated using survey data from a single season. These yields were compared with (a) modelled yield and (b) experimental output in farmers' fields during the same season. Trials were created and handled by researchers following suggested procedures in an effort to achieve a high yield. Modeled yield was characterized by the authors of the research as "climate-driven potential," which corresponds to the definitions of Yp or Yw depending on water availability.

The best farmer yield of wheat, maize, and aggregated wheat-maize was close to the experimental output, and around 78–89% of potential yield calculated using models (Figure 18). This finding suggests that there is no residual exploitable gap for the top farmers. The difference between the average yield and the best yield was around 30 percent for each individual crop and for the whole system. Liang et al. (2011) identified agronomic and socio-economic factors that were the fundamental cause of yield disparities. Their findings were based on interviews and field observations. For instance, the inability to use shared irrigation infrastructure makes it impossible to implement the suggested strategy of irrigating wheat stems during the elongation stage.

Approach 2: Boundary Functions Accounting For Resources And C

The crop yield is a result of both the capture rate and the efficiency with which resources are used, as well as the non-resource restrictions that modulate crop growth, morphology, and physiology (Figure 4.3). Methods that are founded on the idea of boundary functions have

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been developed in order to take into consideration both resource-based and non-resource-based aspects of the natural environment (Box 3). In order to establish a baseline for yield in respect to resources, most notably water (Section 4.2.1) and nitrogen (Section 4.2.2), as well as soil restrictions, boundary functions have been used (Section 4.2.3).

Yield And Water Productivity Gaps

This method was first used by French and Schultz (1984a, 1984b) for rain-fed wheat in Australia. In more recent years, it has been adapted for use in a variety of rain-fed and irrigated cropping systems all over the globe. The technique may be used to manage water use throughout the whole season, or it may be restricted to crop-specific key times.

Wheat grown in systems dependent on rain

Wheat yield in south-eastern Australia was benchmarked by French and Schultz (1984a, 1984b), who also highlighted managerial and environmental factors of the difference between actual and feasible yield. In this article, we provide an overview of the idea as well as an updated benchmarking of wheat in dryland settings.

The authors plotted the grain yield versus the evapotranspiration (ET) of wheat crops, measured as soil water at sowing plus in-season rainfall, across a variety of locations and times of the year, and then fitted a boundary line with biophysically relevant parameters (Figure 4.3a):

$$Yw = TEY * (ET - E)$$

The slope, TEY, can be interpreted as the maximum transpiration efficiency for the production of grain. The x-intercept, E, can be interpreted as non-productive water loss, which is primarily caused by soil evaporation. Where Yw is the water-limited yield, TEY can be interpreted as the maximum transpiration efficiency. The slope of 20 kg grain ha-1 mm-1 was determined to be the typical slope in the first investigation, and this was confirmed by physiological considerations. The authors acknowledged that the x-intercept was dependent on climatic circumstances, most importantly rainfall and soil, and proposed a range for crops in eastern Australia of between 30 and 170 mm. For instance, a rainfall total of 30 millimeters would be more typical of locations in the north, where water supply relies heavily on the

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soil's capacity to hold moisture and where there are comparatively few, typically significant rainfall events during the season. Towards the south

Yield Gaps And Nitrogen Uptake

In the light of rising prices for both energy and fertilizer, as well as concerns about nitrogen leaching and greenhouse gas emissions, benchmarks that are based on the capture of nitrogen are significant not just agronomically but also economically and ecologically.

Savin et al. (2006) used the relationship between actual wheat yield and nitrogen uptake to investigate putative differences in nitrogen use efficiency between Mediterranean and non-Mediterranean environments. This was done by comparing wheat grown in Mediterranean environments to wheat grown in non-Mediterranean environments (Figure 26). The boundary functions showed a reduced efficiency in circumstances typical of the Mediterranean region, which has been hypothesized to be connected with hotter temperatures during grain filling. The curves shown in Figure 26 are empirical, and in a manner similar to the methodology based on water consumption (Section 4.2.1.1 to 4.2.1.4), they take into consideration the seasonal capture of a significant agricultural resource. The fact that grain nitrogen content is responsible for a considerable portion of the difference between the actual yield and the achievable yield (Savin et al. 2006; Ciampitti & Vyn 2012), means that the use of this method to benchmarking is limited.

Yield Gaps And Soil Constraints

A soil-focused methodology was used by Casanova et al. (2002) in order to quantify yield gaps of irrigated rice in the Ebro Delta of Spain. In each of the 50 fields, they took readings of the yield (y) as well as the soil texture and chemical qualities (xi). The following procedures were followed in order to determine a boundary line for each of the xi variables: (a) each xi was separated into one of ten groups, (b) the frequency distributions of yield for each xi were analyzed to determine whether or not they were normally distributed, (c) the average xi and yield at 95% confidence were chosen for the groups that passed the normality test, and (d) a linear regression model was created utilizing the chosen xi and yield. This method resulted in the generation of boundary lines that had a positive slope for variables of the resource type, such as cation exchange capacity, and a negative slope for variables of the constraint type, such as salinity.

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Water Productivity As A Function Of Yield

It has been shown that there is a non-linear relationship between grain production and water productivity, using examples from rainfed and irrigated wheat fields in the United States (Musick et al. 1994). This method has not been employed before, but the study shown in Figure 28 for maize in the Doukkala Irrigation Scheme of Morocco indicates how boundary functions might be used to capture the top limit of water productivity, identify underperforming areas, and calculate water productivity gaps.

APPROACH 3: M

Both Approach 1 and Approach 2 under-estimate the maximum yield in situations when best practice cannot be implemented. For instance, when constraints imposed by policy or infrastructure preclude the use of inputs like fertilizer. In this part of the report, we collect a series of case studies, including a comparison of yield benchmarking and gap analysis utilizing on-farm yields (Approach 1) and simulated yield (Approach 3) with maize in the United States of America and Kenya, as well as wheat in Australia.

Rice in Southeast Asia, maize in Zimbabwe, and quinoa in Bolivia are the subjects of three further case studies. The use of climate indicators to predict potential yield as well as the AgroEcological Zones concept developed by the FAO are both explained in this article.

Maize (Usa, Kenya) And Wheat (Australia)

Van Ittersum et al. (2013) investigated the potential repercussions of assessing the yield gap at a local level using a variety of methodologies that were either based on simulated or real yields. The following approaches were assessed for their capacity to predict potential yield or water-limited production for irrigated and rainfed cropping systems, respectively, and their accompanying yield gaps, across farmer's fields that were located in very small geographic areas:

• site-specific simulation of potential or water-limited yield using crop growth models; • derivation of potential or water-limited yield from upper percentiles of farmer yield distributions; • maximum yields measured in experimental stations, growers contests, or the fields of the highestyielding farmer's fields.

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Rainfed maize in western Kenya, irrigated maize in Nebraska (USA), and rainfed wheat in Victoria, Australia were the agricultural systems that were taken into consideration for this investigation. Each of these cropping systems included a different amount of intensification (Australia). For every farmer's field in Nebraska and Victoria, information was accessible for three years' worth of years on yield, management, weather, and the qualities of the soil; for Kenya, just one year's worth of information was available. In previously published works, one may find detailed descriptions of cropping systems, as well as the construction and validation of crop models, as well as the data inputs (Grassini et al. 2011; Tittonell et al. 2006; Hochman et al. 2009).

Rice In Southeast Asia

Researchers Laborte et al. (2012) analyzed the yields of farmers and the gaps in those yields during the wet and dry seasons in four intensively cropped rice areas in Southeast Asia: Central Luzon in the Philippines, West Java in Indonesia, Suphan Buri in Thailand, and Can Tho in Vietnam. All of these areas are located in Southeast Asia.

The yield gaps were assessed based on the potential yield that was determined using the crop growth model ORYZA2000 by applying crop development rates that were computed from observable phenological phases, real crop establishment techniques, and actual average planting dates of farmers (Bouman 2011).

Estimates of exploitable yield gaps (section 2.2) were derived using economic yields (equal to 80% of potential yield) and the yields of the best farmers (upper 10 percentile in each year, season, and site).

Maize In Zimbabwe

Kahindae et al. (2007) investigated various farming strategies to narrow the yield gap of maize in semi-arid Zimbabwe using a simulation model called APSIM. They predicted two very high yields, one of which was the highest possible with an adequate supply of water or nitrogen, and the other was a rainfed control yield that was more comparable to typical agricultural operations despite the absence of fertilizer and extra irrigation. Within the confines of these extreme yields, a variety of doable choices were modeled, such as using a mix of locally devised rain water gathering systems and minimal quantities of inorganic nitrogen or manure. These options were considered within the context of these extraordinary

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yields. The results of this modeling experiment demonstrated the synergy that exists between water and nitrogen, which is in line with both theoretical and empirical concerns (Sadras 2005; Cossani et al. 2010).

Quinoa In Bolivia

In the Bolivian Altiplano, where the yields of rainfed crops are low and variable, Geerts et al. (2009) utilized the AquaCrop model to investigate the possibility of increasing quinoa production by irrigation in order to close yield gaps. The various simulated scenarios included a rainfed control, a reference strategy that avoided stomatal closure during all sensitive growth stages and allowed drought stress during the tolerant growth stages, and a variety of restrictive deficit irrigation strategies representing cases when water resources are limited. All of these were compared to one another through computer modeling. The results of the scenario analysis were used to construct probability curves for three different agro-climatic zones. The simulated yields of rain-fed quinoa during dry years ranged from 1.1 tons per hectare in the northern region to 0.2 tons per hectare in the southern Altiplano. These yields increased to 2.2-1.5 tons per hectare with the best irrigation treatment, which corresponded to yield gaps of more than 1 ton per hectare. It was determined that a minimum availability of water on the order of 600–700 m3 per hectare is necessary in order to achieve considerable reductions in yield gaps in the central and southern areas.

Estimating Yield Potential With Climate Indices

The preceding sections provided examples of yield gap analysis based on simulation models that took into consideration the effects of elements such as the environment, crops, and management. In this part of the article, we will discuss more straightforward approaches to taking into account important climatic determinants in the definition of yield potential (section 2) and their use in benchmarking. Fischer (1985) came up with the concept of a photothermal quotient (PTQ) to describe the relationship between solar radiation (Rad) and mean temperature (T) above a base temperature (Tb) within a time frame that included the most crucial time for grain set:

$$PTQ = Rad / (T - Tb)$$

This coefficient is a reflection of four physiological principles, which are as follows: (a) grain number is the primary component of yield (Sadras, 2007b); (b) grain number is proportional

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to total growth during a species-specific critical window around flowering (Andrade et al., 2005); (c) growth rate during this critical window is proportional to photosynthesis and, as a result, radiation; and (d) the duration of this period is inversely proportional to temperature. On the basis of these principles, Fischer's (1985) photothermal quotient and other related indices often capture a large portion of the variance in grain production of various annual grain crops (Fischer 1985; Cantagallo et al. 1997). According to the research that was conducted by Bell and Fischer (1994) and presented in Section 3.2.2, the rate of change in wheat yield in the Yaqui Valley of Mexico calculated with the photothermal quotient was comparable to the rate calculated with CERES-wheat, despite the fact that estimates were off by approximately 0.8 t. In order to produce location-specific benchmarks for wheat production in the Pampas, estimates of grain number were calculated with the use of a photothermal coefficient, and the kernel weight was either modeled (Menendez and Satorre 2007) or measured (Calvio and Sadras 2002).

CONCLUSION

When choosing a spatial scale for benchmarking, it is important to take into account the specifics of the task at hand. It is necessary to do benchmarking at the field level in order to, for instance, increase the yield at the farm size. In addition to the geographical scale, the temporal scale should also be taken into mind. The time scale needs to be long enough to capture as much variation in seasonal conditions as possible, while also being short enough to meet the assumption of constant technology. If the goal is to benchmark crops using the technology that is currently available, then the time scale needs to be long enough. Benchmarking that takes into account the temporal patterns associated with technical advancement, rates of adoption, and environmental change is made possible by adopting a dynamic approach.

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