How much land per person do we need in south India to feed ourselves?

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1 Introduction

Impressed by the visual and educational impact created by a poster talking about the agricultural area required by humans, placed in front of a designated 2000-squ.m. plot in Jaerna, Sweden, we considered it worthwhile to produce a similar educational feature on one of the organic farms in Auroville, Tamil Nadu, where we are at home. Prior to creating such a visual display we wanted to make sure that the figures we use for publication are realistic in the context of the tropical to subtropical conditions in Tamil Nadu. The information gained would be used to educate farmers who visit the organic farms of Auroville in the context of training exposures and knowledge exchange, as well as all non-farming visitors. – This was the research task assigned to me.

2 Daily intake of kilocalories

The recommended daily intake of kilocalories for one individual depends upon several factors such as, for example, age, height, weight, gender and activities. However, WHO/FAO estimate a recommended daily intake of 2000 kilocalories for adult women and 2550 kilocalories for adult men; thus, they arrive at a recommendation of approximately 2300 kilocalories for an adult a day [12]. Incidentally, this estimate matches the amount of food available for human consumption in India which, according to the FAO Statistic Division, was 2360 kilocalories in 2006-2008.
Further, WHO/FAO recommend that, of the said 2300 kilocalories, 15% is to be provided as proteins, 30% as fats and 55% as carbohydrates.
2300 kcal a day × 365 days = 839,500 kcal a year for an adult.

839,500 kcal a year × 0.55 (recommended daily intake of carbs) ≈ 461,700 kilocalories from carbohydrates a year for one adult.

839,500 kcal a year × 0.30 (recommended daily intake of fats) ≈ 251,900 kilocalories from fats a year for one adult.

839,500 kcal a year × 0.15 (recommended daily intake of proteins) ≈ 125,900 kilocalories from proteins a year for one adult.

3 Possible crops

In southern India common crops are rice and lentils, which must be regarded as staple food crops. But we need additional crops providing fats, for which we may consider peanuts, sesame and sunflower seeds, as they all grow under tropical conditions.

percentage of	in rice [2]	in lentils [3]	in peanuts [5]	in sesame [10]	in sunflower seeds [14]
fats	0.6	1.3	48	50	51
carbs	77.8	60	21	23	20
proteins	6.8	25	25	18	21

In general the metabolizable energy factors are as follows: for fat 9.00 kcal/g, for carbohydrates 4.00 kcal/g and for proteins 4.00 kcal/g. [1]

3.1 Rice, lentils, peanuts

In order to describe the annual intake of kilocalories from fats (using rice, lentils and peanuts as crop sources) we can use this equation:

$$0.006 \times R \times 9.00\frac{kcal}{g} + 0.013 \times L \times 9.00\frac{kcal}{g} + 0.48 \times P \times 9.00\frac{kcal}{g} = 251,900kcal$$
(1)

Here R stands for the quantity of rice in gram, L for the quantity of lentils in gram and P for the quantity of peanuts in gram. Analogue to this equation we can describe the annual intake of kilocalories out of carbohydrates (2) and proteins (3) with similar equations:

$$0.778 \times R \times 4.00\frac{kcal}{g} + 0.60 \times L \times 4.00\frac{kcal}{g} + 0.21 \times P \times 4.00\frac{kcal}{g} = 461,700kcal$$
(2)

$$0.068 \times R \times 4.00\frac{kcal}{g} + 0.25 \times L \times 4.00\frac{kcal}{g} + 0.25 \times P \times 4.00\frac{kcal}{g} = 125,900kcal$$
(3)

We can simplify these equations and omit the very small terms in equation (1).

$$28,000g = 0.48P \tag{4}$$
$$115,000g = 0.778R + 0.60L + 0.21P \tag{5}$$
$$31,500g = 0.068R + 0.25L + 0.25P \tag{6}$$

Thus $P \approx 58,300g$. Inserting this into the other two equations, we get:

$$102,800g \approx 0.778R + 0.6L \tag{7}$$
$$16,900g \approx 0.068R + 0.25L \quad \text{or} \quad L \approx 67,600g - 0.272R \tag{8}$$

Inserting equation (8) into equation (7):

$$102,800g \approx 0.778R + 0.6(67,600g - 0.272R) \tag{9}$$
$$R \approx 101,235g \tag{10}$$

Thus,

$$L \approx 67,600g - 0.272 \times 101,235g \approx 40,100g \tag{11}$$

As a result we conclude that we need approximately 58.3kg of peanuts, 101.2kg of rice and 40.1kg of lentils to obtain the recommended intake of kilocalories out of carbohydrates, fats and proteins for one person for one year.

In the following we shall examine how much acreage is required to grow adequate amounts of rice, lentils and peanuts.

We will use Annapurna farm as a prototype in Tamil Nadu. As of now, the farm reached its largest yield in the season 2004-2005 with 2250kg paddy per acre. During the past years however, yields have generally reached around 1300-1500kg per acre, in average about 1400kg per acre. 1400kg paddy per acre will, after dehusking, provide 1120kg of brown or unpolished rice and 1050kg of white or polished rice. One acre of paddy providing 1400kg of paddy i.e. rice in the husk, generates 1050kg of white or polished rice. On the assumption that an adult requires 101.2kg white rice per year, one acre providing 1050kg of rice (in one season) will feed ca. 10 persons with white or polished rice. As $1 acre = 4046.86m^2$, one person needs about $405m^2$ per year for the required amount of rice.

In the period 2012-15 the average annual productivity of lentils in India was 701kg/ha [4]. Lentils can be eaten unpolished. On the assumption that an adult should eat 40.1kg of lentils a year, one ha providing 701kg of lentils would feed ca. 17.5 persons. Thus, a single person needs about $571m^2$ per year for the required amount of lentils.

In the financial year 2015/16 the average productivity of peanuts in Tamil Nadu was 685kg/ha [6]. After removal of the hull which accounts for approximately 25% of the

groundnut in shell [7], the average yield figure is 513kg/ha. On the assumption that an adult should eat 58.3kg of peanuts a year, one ha providing 513kg of peanuts would feed ca. 9 persons. Thus one person needs about $1100m^2$ per year for growing the adequate amount of peanuts.

In sum, a single person needs $2076m^2$ to generate the (yearly) requirement of kilocalories out of carbohydrates, fats and proteins.

3.2 Rice, lentils, sesame

In analogy to the first system of linear equations, we set up a linear system of equations for rice, lentils and sesame, here already shown in the simplified version:

$$28,000g = 0.50S \tag{12}$$
$$115,000g = 0.778R + 0.60L + 0.23S \tag{13}$$
$$31,500g = 0.068R + 0.25L + 0.18S \tag{14}$$

Thus $S \approx 56,000g$. Inserting this into the other two equations, we get:

$$102,120g \approx 0.778R + 0.6L \tag{15}$$
$$21,420g \approx 0.068R + 0.25L \quad \text{or} \quad L \approx 85,680g - 0.272R \tag{16}$$

Inserting equation (16) into equation (15):

$$102,120g \approx 0.778R + 0.6(85,680g - 0.272R) \tag{17}$$
$$R \approx 82,500g \tag{18}$$

Thus,

$$L \approx 85,680g - 0.272 \times 82,500g \approx 63,200g \tag{19}$$

We conclude that we need 56kg of sesame, 82.5kg of rice and 63.2kg of lentils to get the recommended intake of kilocalories from carbohydrates, fats and proteins for one person for one year.

In the following we shall examine how much acreage we need to get the adequate amounts of rice, lentils and sesame.

As elaborated above, and under the assumptions that one adult should eat 82.5kg of rice, and that one acre provides 1050kg of rice feeding ca. 13 persons with white or polished rice per year, we conclude that a single person needs about $311m^2$ to grow the adequate amount of rice.

Further, as elaborated above, and under the assumptions that one adult should eat 63.2kg of lentils, and that that one ha provides 701kg of lentils feeding ca. 11 persons,

we conclude that one person needs about $909m^2$ per year for the adequate amount of lentils.

In 2005/06 the average of productivity of sesame in Tamil Nadu was 470kg/ha [8]. Sesame does not require any hulling, but is typically used for oil extraction. Under the assumptions that one adult requires approximately 56kg of sesame a year, and that one ha provides 470kg of sesame feeding ca. 8 persons, we conclude that one person needs about $1250m^2$ to obtain the adequate amount of sesame.

In sum, a single person needs $2470m^2$ to generate the (yearly) requirement of kilocalories out of carbohydrates, fats and proteins.

3.3 Rice, lentils, sunflower seeds

In analogy to the first system of linear equations, we set up a linear system of equations for rice, lentils and sunflower seeds, here already shown in the simplified version:

$$28,000g = 0.51S \tag{20}$$
$$115,000g = 0.778R + 0.60L + 0.20S \tag{21}$$
$$31,500g = 0.068R + 0.25L + 0.21S \tag{22}$$

Thus $S \approx 54,900g$. Inserting this into the other two equations, we get:

$$104,020g \approx 0.778R + 0.6L \tag{23}$$
$$19,971g \approx 0.068R + 0.25L \quad \text{or} \quad L \approx 79,884g - 0.272R \tag{24}$$

Inserting equation (24) into equation (23):

$$104,020g \approx 0.778R + 0.6(79,884g - 0.272R) \tag{25}$$
$$R \approx 91,200g \tag{26}$$

Thus,

$$L \approx 79,884g - 0.272 \times 91,200g \approx 55,100g \tag{27}$$

We conclude that we need approximately 55.1kg of sunflower seeds, 91.2kg of rice and 55.1kg of lentils to obtain the recommended intake of kilocalories out of carbohydrates, fats and proteins for one person for one year.

Again, in the following we shall examine how much acreage we need to get the required amounts of rice, lentils and sunflower seeds.

As elaborated above, and under the assumptions that one adult should eat approximately 91.2kg white rice a year, and that one acre provides 1050kg of rice feeding ca. 12 persons with white or polished rice per year, we conclude that a single person needs about $337m^2$

per year for the adequate amount of rice.

Further, as elaborated above, and under the assumptions that one adult should eat 55.1kg lentils a year, and that one ha provides 701kg of lentils feeding ca. 13 persons, we conclude that one person needs $769m^2$ per year for the adequate amount of lentils.

In 2009/10 the average productivity of sunflower seeds in Tamil Nadu was 1328.7kg/ha. We note that in Tamil Nadu sunflower fields are often irrigated. Under the assumption that one adult should eat 54.9kg of sunflower seeds a year, we conclude that one ha provides 1328.7kg of sunflower seeds which would feed ca. 24 persons. Thus, one person needs about $417m^2$. In India as a whole, the average productivity of sunflower seeds was only 900kg/ha [9]. Using this value, one ha would feed ca. 16 persons. Thus, one person needs about 625 m^2 for the adequate amount of sunflower seeds.

In sum, a single person needs $1731m^2$ to generate the requirement of kilocalories out of carbohydrates, fats and proteins.

4 Conclusions

We conclude that in southern India at least ca. $1731m^2$ are required to grow the food for one individual. However, several additional factors and variables would need to be taken into consideration.
Yield data given for rice, lentils and peanuts explicitly refer to a single season, while the yield data for sesame and sunflowers are given as annual figures which are assumed to be single-season figures. Rotation crops between the seasons may be nutrient-fixing crops or leguminous crops other than lentils and peanuts, or fields could be left fallow. These practices have a great impact on the yields of the crop in discussion.
Further, as differences in weather affect the yield, the average yield figures of a single year or of short periods of time do not necessarily represent average figures over longer periods, hence the required area would be different.
Then, as already stated, the average daily requirement of kilocalories varies hugely with age, height, weight, gender and activities. Most importantly, a hard working man needs much more than 3000kcal and thus would require a larger acreage.
Next, my calculations neglected the requirements in vitamins, minerals and trace elements, hence it cannot be claimed that the suggested area will provide all essentials. Lastly, I also neglected variations in synthetic fertilizers, organic composts and other external inputs, which could influence the yields to a great extent and hence change the figures of needed acreage.

According to Scheub, Ute et al. (2013), Terra Preta: Die schwarze Revolution aus dem Regenwald, the needed acreage per person in industrial agriculture in the tropics is about $1800m^2$. This value is close to the combination of rice, lentils and sunflower seeds requiring $1731m^2$. The other crop combinations would require significantly larger areas.

According to a study of the European Union [11] the area at an individual's disposal would be $2000m^2$ if all the arable land globally was divided among all people living on the planet. This figure is close to the area figures of my first and my third crop combination i.e. rice, lentils and peanuts, and rice, lentils and sunflower seeds.

As per census 2011 Tamil Nadu has a population of 72,147,030 and a cultivated area of 5.6 million ha [13]. It follows that the area at an individual's disposal is $776m^2$. We conclude that Tamil Nadu does not have sufficient agricultural land to feed the populace of the state and that it must be a food-importing state within India.

5 Sources

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