Introduction

When belief in established institutions and practices declines, the search for comprehensive philosophies of life and rival policies compete in the name of one or another Weltanschauung. (Eric Roll, 1938, A History of Economic Thought, Fifth impression, Faber and Faber, London, p. 23)

This thesis defines the sustainability of agriculture in terms of whether the farm household is able to yield an energy surplus, when its members and the animals in its possession are obtaining an adequate Calorie intake. Appropriate Calorie norms have been assumed, their fulfilment being a necessary but not a sufficient condition for the generation of surplus. Further, the route this thesis has taken, does not look into the magnitude of the actual surplus or its distribution. The latter is based on the property relations, which can be extremely exploitative in nature. Even while producing an adequate energy surplus for the members and the animals in the sense defined in this thesis, a household can end up with a negative surplus because property relations are such that it gets expropriated. Thus, the results of this thesis show only the upper bound of the number of households producing a surplus, without the consideration of the factor incomes.

The method employed in such an evaluation is the energy balance analysis, which takes into account not just the economic but the ecological dimension as well. In fact, it is independent of the prices of inputs and outputs altogether. Energy is taken as the standard. This approach is motivated by the agrarian distress that has received much attention in the recent times: be it the farmer's suicides of epidemic magnitude in many parts of the country, or the rising food prices. Arguably, at the minimum, it indicates that the agricultural production system has been in a state of great stress, in terms of its capacity to sustain an adequate surplus. The direct, obvious and visible human society-nature interactions and exchanges in agriculture necessitated foraying into the intersection of the two disciplines, ecology and economics, or ecological economics.

Surplus, conceptually speaking, has undergone significant changes in the past two and half centuries of economic thought. The standard in terms of which both inputs and output are measured moved even in early years of economics from corn to embodied labour. Certainly, a logical extension is the embodied energy measured with the units of Calorie (kcal) or Mega-joule (MJ). Apart from its
being a convenient standard, there also exist a number of arguments, supporting such a development, of which a few may be listed here.

First, price or wage or income, and in the process, the problems related to imputation can be avoided altogether. After all, in agriculture, for most of the inputs and outputs, the markets either do not exist or are heavily distorted. Second, the use of 'energy income' or food calorie for the human labourers certainly has served as a norm for identifying the productive capacity of their labour power, as manifested in the construction of poverty lines. The third reason is the impending crisis facing the present mode of energy use which is exhausting the non-renewable low entropy ones at a much faster rate than they could be produced. Clearly, there is a need to combine appropriately the non-renewable and renewable sources of embodied energy in the inputs, excluding the living labour, for the sustainability of the surplus. There are many other compelling reasons, to be discussed as we progress. In sum, we may restate the objective: to explore the possibilities of augmenting the surplus from agriculture, through an energy balance analysis.

For the purposes of comparison, the analysis was carried out across two time-periods in the State of West Bengal: the year 2004–05 represents the 'modern' chemical based agriculture, while it is 1956–57 for the traditional type of organic farming. Admittedly, the latter is one of the many varieties of the organic methods of crop production, and as a result, conclusions of the thesis, will be limited to this particular type only.

This chapter is devoted to the development of concept of surplus towards establishing the connection between the surplus and its sustainability using the method of energy balance analysis. Chapter 2 will discuss the method itself, along with the specific assumptions made in this work. Various energy values or coefficients are also included. Some of the conceptual issues linking surplus and the energy balance analysis, towards defining four alternative scales of sustainability employed in this thesis will be presented in Chapter 3 along with a brief description of the 2004–05 dataset. Chapter 4 will explore the sustainability of agriculture in West Bengal in 2004–05 through some of the results. The following chapter will be engaged with the patterns of input usage in 2004–05.
and their impact on surplus along with the constituents of output. A comparison between the traditional and the 'modern' methods will be offered in chapter 6. Finally, chapter 7 will summarise the thesis with a conclusion.

1.1. Development of the Concept of Surplus

Physiocrats mark the beginning of the 'curious sociological phenomenon' called 'school of thought' in the history of economics (Meek 1962: 27; Roll 1938: 130); at times, this set of French economists are also regarded as pioneers in classical political economic thought.¹ Like Adam Smith, for François Quesnay the fundamental economic problem was to inquire into the nature and causes of the 'wealth of nations': 'Of what did wealth consist? How was it produced and increased? And, in particular, what action should be taken to maximise its rate of increase?' (Meek 1951: 26; also, Bharadwaj 1978: 14).² These are precisely the questions for the present thesis as well.

¹ To be more precise, it was the celebrated interview between a 69 year François Quesnay and 42 year Marquis de Mirabeau to discuss latter's Friend of Mankind, towards the end of July 1757, at the Palace of Versailles: 'at this interview the potential disciple was won over, and from that date to his death played the role of Engels to his master's Marx' (Meek 1962: 15).

For Schumpeter (1976: 223), the fidelity of the Physiocrats to absorb and accept their master's teachings had 'but two analogues in the whole history of economics: the fidelity of the orthodox Marxists to the message of Marx and the fidelity of the orthodox Keynesians to the message of Keynes'. Meek (1962: 370) joined many others in arguing that 'Physiocrats took the decisive step leading from politics to political economy'. However, for Roll (1938: 22) political economy could appeared as 'a science' only when the foundations of industrial capitalism were well established. In particular, it came to maturity during the forty years between Wealth of Nations and Principles. Its roots were threefold—first, the philosophical, from 'its canonical origin to philosophic radicalism'; second, progress of the English economic thought since later Mercantilists; and third, Physiocrats (1938: 88).

On the other hand, consider Leontyev (1968: 21), notwithstanding the polemics:

Political economy studies the most important aspect of society's existence and advance—its economic life. Disclosing the laws governing social production, it provides the key to an understanding of the whole complex process of social development. [...] Political economy deals with the burning problems of the class struggle. It studies the vital interests of the main classes of capitalist society. What is more, it poses and answers the question of the very existence of the society. For that reason, political economy cannot be neutral in the class struggle. On the contrary, it is a class, a party science. All talk of a neutral or above-party political economy is no more than a guise for economists who, defending the interests of the moribund classes, prefer not to reveal their true face.

Also see, Marx (1954a: preface), Dobb (1973: 142fn), and Bharadwaj (1978: 10)

² The following had engaged the 'most speculative minds':
(a) what does this surplus consist of and what determines is size, (b) where does it originate, (c) among whom is it distributed, (d) how, i.e. by what principles, is it distributed, (e) what determines its growth over time, (f) what happens to the relative shares of surplus accruing to the different classes of appropriators as the size of the surplus increases? (Bharadwaj 1978: 14)
Notions of ‘wealth’ had undergone a tremendous change from stock to flow with the Physiocrats (Pasinetti 1977: 2–3). The former refers to the abundance of the stock of goods at the disposal of an individual or of a community while the flow dimension refers to the income of a country in terms of its production of goods and services. For a significantly long time, at least before the industrial revolution in Britain, wealth meant endowment of available economic resources, represented most dramatically by the Mercantilists’ position. For Physiocrats, production and distribution quite prominently featured in the concept of wealth as a flow. A given stock was to be continually consumed through its employment in the process of employed and replaced by this process itself: additionally, in the process, the ‘given’ was to be enlarged. Such an idea of circularity of flow remained with the classical economists, to be revived later by Pierro Sraffa in the mid-twentieth century. Mayumi (2001a) had shown that, formally, embodied energy input-output framework is identical to the Sraffian framework expressed in the current and dated labour terms (Burkett 2003: 139). Mayumi (2001a) in fact had compared the theoretical basis of embodied energy analysis using Sraffian approach and flow-fund model of ‘bio-economist’ Georgescu-roegen (1971: 219–234) and found conditions under which the Sraffa’s and Georgescu’s analyses converged.

The first necessary step for the classicists was to divide the annual produce received directly, into two parts. One was towards the replacement or compensation against those items physically used up during the production process within a referred period, while the second was the net social gain or the

3 Anne-Robert-Jacques Turgot, one of the most politically influential Physiocrats, had explained produit net, one of the key contributions of this school of thought as the following: The produce of the land divides into two parts. The one comprehends the subsistence and the profits of the husbandman, which are the rewards of his labour, and the conditions on which he agrees to cultivate the field of the proprietor; the other which remains is that independent and disposable part, which the earth produces as a free gift to the proprietor over and above what he had disbursed (quoted in Stokes 1992: 24).

4 Flow of commodities from one class to another, in the form of exchanges, was essential at the end of each production period so that the produced wealth be distributed among the various members of the society, in order to continue the production process in the next period: the famous Tableau Economique represented these flows (Pasinetti 1977: 5; Stokes 1992: 25).

5 Resonance of such similarities could also be found in their criticism: After all, such energy analysis is essentially an energy theory of value, and why should one take seriously any movement which simply replaces Marx and the discredited labor theory of value with Carnot and thermodynamics? Energy is but one of many scarce inputs, and the beauty of the market price system is that it provides incentives for the combined wise use of all scarce inputs, not just energy. (Berndt 1982: 3)
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'disposable' surplus, to be either consumed 'unproductively' by the community or for increasing its productive powers. The latter, by definition, was not connected with maintaining the productive powers of the community intact, and was denoted by diverse terms like 'produit net', 'net real income', 'disposable income' or even 'surplus' (Meek 1951: 27, 1962: 346). It could have been defined also as 'surplus energy' or the 'energy available to man in excess of that expended to make more energy available' (Cottrell 1955/2009).  

Indeed, the central question for classical political economy remained the modi operandi for increasing the size of the second part. The first part, on the other hand, was assumed as given in the theoretical formulations as well as in the calculations. Thus, satisfaction of this condition for sustaining the productive powers of the community or the community itself was taken as the necessary one for augmenting the surplus. This thesis employs such a notion of sustainability as one of its core concepts.

'Value' appeared first in the classical economic thought with respect to the quantification of this surplus and comparison of the magnitudes of surplus over different time and space (Bharadwaj 1978: 20). The present thesis computes the

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6 At any given moment of time a person, a group, or any other socially functioning unit has available a limited supply of energy. This can be utilized immediately in its present form. It can also be used in an operation designed to increase the future supply of available energy. The simplest example would be grain, which may be eaten or planted. It is obvious that if the planter does not even get his seed back from the harvest, he has less energy at his disposal than he previously had: he has incurred a deficit. On the other hand, if he harvests enough grain to replace the seed, to supply the amount of energy expended making the tools or machines he used in planting, cultivating, and harvesting his crop, plus his labour and something more, he has gained energy beyond that which was previously his to command: he has surplus energy. 

[...] Surplus energy becomes a key factor in any social system but there are only a few ways to get it. All of them are limited. To get those surpluses man has to discover the sources and build converters that will change his potential into forms of energy that man can use. So he is dependent both upon his ability to find and possess the raw materials furnished by nature, and to design and create converters that will make the energy in them available to man in the forms and at times and places he wants them. The energy expended in doing this must be subtracted from the energy resulting in it. Only the result is net surplus. (Cottrell 1955/2009)

7 Sir William Petty had been referred as the founder of political economy by many (Roll 1938: 102). Occupations of 'cabin-boy, hawker, seaman, clothier, physician, professor of anatomy, professor of music, surveyor, and wealthy land-owner' could have influenced him to declare that 'Labour is the Father and active principle of Wealth, as Lands are the mother' (William Petty, 1662, A Treatise of Taxes & Contributions ..., N. Brooke, at the Angel in Cornhill, London, p. 68, as cited in Roll 1938: 106). It may have also led him to posit that food required by the labourer determined value and price: 'The day's food of an adult Man, at a Medium, and not the days of labour, is the common measure of value' (cited in Roll 1938: 107).
surplus in various parts of the State of West Bengal, located in Eastern India for selected food crops across two different time-periods, almost 50 years apart.

Such an analysis of the necessary conditions for surplus was carried out in a framework which is closer to those theories of value where the ‘search’ for the origin of surplus is conducted within the sphere of production and not in exchange as in ‘supply-and-demand-based approach to explanations of value and distribution’ (Bharadwaj 1978: 10). The strength of such ‘classical’ approach rests in its ‘openness’, of the possibility of allowing for a wide range of historical, socio-political factors to enter into the determination of “quantities”, that is, output, consumption, methods of production’ (Bharadwaj 1989: 10).

1.1.1. Form, Constituents and Size of Social Surplus
The ‘first and foremost unifying link’ that Bharadwaj (1978: 14) had noted among the classical political economists was their ‘recognition of the distinction between processes of production and those of circulation from the point of view of the generation of surplus’. Marx had put this in the most precise yet comprehensive manner that while surplus originates in production, it is realised in circulation (Bharadwaj 1978: 15).

Surplus was necessary for the new capital to be accumulated, and for the early contributors of 'scientific' political economic thought, like Quesnay, it was seen as the only possible source, as in Wealth of Nations (Meek 1951: 27). It could be traced in the recommendation for the application of capitalist methods in agriculture and manufacture alike by the later Physicrats like Du Pont, Baudeau

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8 Pasinetti (1977: 24–26) had pointed to the dominance of formal economic thinking by marginal economic analysis since 1970, who 'had left aside the phenomenon of production' and the 'the problem it deals with is the optimal allocation, through exchange, of a certain initial endowment and distribution of resources'. Admittedly, this 'model of pure exchange' was modified subsequently to include the process of production in the form of marginal productivity theory, but in such a way 'as to meet the requirements of a preexisting theory concerning the optimal 'allocation' of certain stocks of resources. [...] [I]t has inevitably contributed to keeping the phenomenon of production in a secondary and subordinate position'.

England (1986: 231–2) had mentioned three important features of the neoclassical production theory: of an 'analytical dichotomy' between factors of production and final outputs, of conceiving production as a 'purely technical and unidirectional transformation of productive factors into commodity outputs' and of attaching no importance to the 'historical process' through which factors of production have come about.
and Turgot, 'responsible for removing feudal trappings from Quesnay's system' (Meek 1951: 27); so was the call for capitalist methods in cultivation in their 'master's' first economic article, Fermiers. Indeed, the key variable or the basic factor determining the expansion or contraction in the dimensions of the circle, or the general level of economic activity was the celebrated 'produit net', i.e. disposable surplus over the necessary cost, whose yield depended on the capacity of agriculture (Meek 1962: 19) (here, the usual caveat applies to the term 'capitalist', following Dobb: 1950). Accordingly the classification of social groups was done on the basis of the ability to yield the 'net product': those in agriculture were deemed as 'productive', occupations like manufacture or commerce were categorised as 'sterile', and the third 'class of proprietors' was thought to have belonged to a 'no-man's land' between these two classes possessing some of the characteristics of the other two.

Physiocracy literally means 'rule of nature' (Cleveland 1999: 126). In Physiocratic understanding, nature was relied upon for deriving the 'economic value'. Produit net from agriculture was seen as a component of an 'original and real substance', made available by nature. Other economic activities were just reworking on it. Here '[a]griculture was inherently capable of yielding a physical surplus, which in

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9 One should, perhaps, at once make it clear that the word "capitalistic" which has become fashionable among some economists, [...] has little in common with Capitalism as a category of historical interpretation. "Capitalistic" has been used by economists in a purely technical sense to refer to the use of so-called "roundabout" or time-using methods of production, and has been largely associated with a particular view of the nature of capital. It has no reference to the way in which the instruments of production are owned, and refers mainly to their economic origin and the extent of their use. (Dobb 1950: 3).

10 Productive 'because the physical quantity of goods it obtains by working on the land can directly seen to be greater than the physical quantity of the same good which had to be used up' (Pasinetti 1977: 5). Meek (1962: 380–383) however, argued that there was [...] nothing peculiarly Physiocratic about the idea that agriculture was inherently capable of yielding a disposable surplus over necessary cost in physical terms. [...] But the Physiocrats were of course concerned to emphasize not only the productive of agriculture in physical terms, but also its productivity in value terms. [...] Agriculture, in their view, was certainly productive in both senses—i.e. it was inherently capable of yielding a physical surplus which in a market economy was inherently capable of being transformed into a value surplus. [...] When the Physiocrats claimed that manufacture was sterile, what they meant was simply that it was inherently incapable of yielding any disposable surplus over necessary cost in terms of value.

11 Physiocrats argued in general terms that labour was the cause but not the source of wealth. Labour's function was to transport wealth from one 'larder' to the other. Clearly, in this understanding labour was passive, 'a machine for changing inputs rather than outputs'. Stokes (1992: 25) pointed that change in productivity in this understanding also depicted similar passivity: no matter what the technological processes or how efficient they were, the source of the product will always be nature, irrespective of the ability of humans to control it. Marx was to give credit to Physiocrats for providing expression to a form of materialism, and to criticize them for failing to see the role of labour in creating value (Burkett 2003: 146).
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a market economy was capable of being transformed into a value surplus' (Stokes 1992: 26).

This philosophy was contextualised within the then France, overwhelmingly agricultural yet different from England with its relative lack of 'enclosures'. A very large number of small peasant proprietors were present with small land and primitive methods living a 'wretched existence' and subjected to rather heavy seigneurial dues, and were often forced to hire out labour in one rural industry or the other.12 Along with this, there were a small number of cultivators with large land holdings, living off cultivation in reasonable comfort (Meek 1962: 23). The specific and chief hindrance towards augmenting the net product—the Physiocrats had realised—was the 'prevalence of small-scale, capital-starved, subsistence farming' (Meek 1962: 24). It was to be substituted by 'large-scale farming by up-to-date methods' aided by 'wealth' or capital to be brought by a new class of 'fermiers', 'the men of substance' (Meek 1962: 24, 26).13 However, '[i]t was not so much men who were required in the country, Quesnay insisted—it was rather wealth' (Meek 1951: 28).14

12 The seigneurial dues and tithes were joined by the multiple taxes imposed by the crown, under severe financial strain following a series of disastrous wars and extravagance of courts, which 'as Physiocrats correctly observed, more often than not had the ultimate effect of increasing the deficit instead of reducing it'. At the same time, privileged classes were exempted from many of the taxes (Meek 1962: 25).
13 Large-scale was referred as the 'proper' cultivation with greater expenditure for the purchase of livestock and greater number of labourers. Small-scale was classified as 'poor' that involved a great amount of labour, but ended up mostly in vain in absence of the necessary expenditure (Meek 1962: 82). Indeed, one of the crucial assumptions in the Physiocrat's model was 'a large kingdom, whose territory, fully cultivated by the best possible methods, yields every year a reproduction to the value of five milliards; [...]' (François Quesnay, 'Analysis' as translated in Meek (1962: 151).
14 It is the wealth of the cultivators which causes the wealth employed in cultivation to be generated: The product of labour of cultivation may be worth nothing or almost nothing to the state when the cultivator cannot meet the costs necessary for proper cultivation. [...] Thus the employment of men in cultivation may be useless in a kingdom which lacks the wealth necessary to prepare the land so that it will yield abundant harvests. But the revenue of landed property is always assured in a kingdom which is well furnished with wealthy husbandmen. (Meek 1962: 74; emphasis as in original)

Land, I repeat, constitutes wealth only because of the fact that its products are necessary to satisfy man's needs, and because it is these needs themselves which lay the basis of wealth. Thus the more men there are in a kingdom with a very extensive and fertile territory the greater its wealth will be. It is cultivation, stimulated by men's needs, which is the most fertile source of wealth and the most important mainstay population. It supplies the materials which are required to satisfy our needs, and procures revenue for the sovereign and the proprietors. Population increases much more through revenue and expenditure than it does through the propagation of the nation itself. [François Quesnay, 1757, 'Corn', translated in Meek (1962: 84)]
The prescribed policies were: imposition of *impôt unique* or single tax on land rent, removal of Mercantilist restrictions on internal and external trade of agricultural produce, and discontinuation of 'exclusive privileges' like subsidies to certain manufacturing establishments, so as to curb the diversion of investment away from agriculture and 'perversion of taste', resulting in a lower demand for agricultural products. These proposals towards increasing the magnitude of the net product by stimulating both output (through replacement of *la petite culture* by *la grande culture*) and price of corn were argued to be the 'essential precondition of the rehabilitation of French agriculture' (Meek 1962: 27). Three successive editions of the famous *Tableau Economique* (1758–59), clubbed with *Philosophie Rurale* (*Rural Philosophy*, 1763) by Mirabeau and Quesnay, 'designed as a sort of basic text-book' of Physiocratic theory and policy, had been marked as the outlining doctrine necessary for the foundation of the 'school' (Meek 1962: 30). Physiocratic system clearly and fully reflected the sharp conflicts that were in the making between the 'decadent feudal order and the emerging capitalist one' (Bharadwaj 1978: 17). The declaration of May 25, 1763 showed the early acceptance of Physiocratic prescriptions in State policies, and the ascent to power by Turgot represented its triumph, which was achieved despite the fact that everyone opposed the Physiocratic doctrine on one ground or the other. The year 1776 marked the end of Physiocratic reforms with the fall of Turgot. It also saw the publication of *Wealth of Nations* (Meek 1962: 34). Despite holding Physiocrats and Smith and his followers within the same genus of 'Classicism', Meek (1951: 29) was quick to point out the important differences in the assumptions that each school had held over the form taken by the social surplus.

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15 The tax-farmers and other 'men of finance' could take exception to the direct attacks made against them; the 'school of Gournay' to the relatively subordinate emphasis given to free trade; the Encyclopedists to the doctrine of 'legal despotism'; the manufacturers and merchants to the description of their callings as 'sterile' and the agitation for the ending of their 'exclusive privileges'; the guilds to the cries for their abolition; the landowners to the advocacy of the single tax and land rent; and the common people to the doctrine of 'proper price' which would make (and in fact appeared to be making) their bread dearer. (Meek 1962: 33)

16 Physiocrats had been attributed by Meek (1962: 370) for bringing forward [...] for the first time in the history of economic thought, [...] the fact that the 'areas of decision' open to policy-makers in the economic sphere have certain limits, and that a theoretical model of the economy is necessary in order to define these limits. We are unfree, the Physiocrats in effect proclaimed, so long as we do not understand the necessities by which we are bound in our society; and we can understand these necessities, in a society as complex as ours, only if we use the methods of simplification, selection, and generalization in our analysis of it. It was in their recognition of this vital fact that the Physiocrats took the decisive step leading from politics to political economy.
Indeed, the basic Physiocratic doctrine of surplus from the land being the sole source of wealth of a nation did have British predecessors (for example, Richard Cantillon, the forerunner of the ‘circular’ conception of economy, or William Petty), but its systematisation in Britain did not take the form it took in France (Meek 1951: 31). Rather, it had been a matter of debate within the British Political Economy in the early years of nineteenth century (Meek 1951: 26). The reasons could be located in the constituents of social surplus and their definitions.

1.1.1.1. *Rent, Profit and Interest*

In Cantillon’s *Essay*, three types of ‘rents’ could be located, which were the principal sources for circulation. Each rent was roughly equal to one-third of the farm’s produce: (1) ‘True Rent’ paid to the proprietor, (2) compensation for the farmer’s costs and subsistence expenses, and (3) a net income ‘which ought to remain with him to make his undertaking profitable’ (Meek 1962: 268). In *Corn*, Quesnay took this approach of putting the farmers’ profit in the net product, but nowhere else (Meek 1962: 268). In fact, an ‘apparent contradiction’ had remained in Physiocrats on the treatment of profit (Meek 1962: 297–8).

Originating from the understanding that surplus could only take the form of land rent, the earth was regarded as the unique source of wealth, and agriculture as the only productive activity. Meek (1951: 29) had argued that there was no ‘net profit’ as a category of income for the early Physiocrats, but ‘interest’ on farmer’s capital certainly existed, to denote the compensation for wear and tear, or acts of god, etc. While ‘exclusive privileges’ could have permitted the manufacturers to receive an income in the nature of ‘net profits’, the latter was regarded either as a superior kind of wage or resulting from the sale of commodities by the entrepreneur to the landowner at a price greater than the ‘real value’ (Meek 1951). Net product was the source of the latter, and therefore, even if the profit on capital existed, it was not an independent category of income, as its origin was still rent.

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17 Influence of Richard Cantillon’s *Essai sur la Nature du Commerce en Général* (*Essay on the Nature of Trade in General*, 1755), was noted by several authors beginning with Marx (1954a, c), as pointed by Meek (1962: 267).

Admittedly, in the understanding of the economic writers prior to the eighteenth century, there were profits, 'the margin between price of sale and price of purchase' which 'might suffice to cover the merchant's expenses, and if he were not too luckless secure him a bare livelihood as well' (Dobb 1973: 199–200). Still, it was difficult to imagine any substantial profit being 'naturally' made by the investment in production. Such profits were unthinkable within conditions of unfettered competition: and thus, 'it is not surprising in this period that profit should have been regarded as fruit of successful speculation, in the sense of taking advantage of price differences. [...] Competition and surplus-value could not endure long in company' (Dobb 1950: 199–200). The notion of profit, as surplus value, without any conscious regulations to produce it, was still distant.

Despite similarities with the Physiocrats as noted earlier, the Smithian school accorded independent status to 'profit on stock' along with 'rent on land', as two parts of social surplus, defined as the difference between the annual produce and cost of production.

"... The whole annual produce of the land and labour of every country, or, what comes to the same thing, the whole price of that annual produce, naturally divides itself, it has already been observed, into three parts; the rent of land, the wages of labour, and the profits of stock; and constitutes a revenue to three different orders of people; to those who live by rent, to those who live by wages, and to those who live by profit. These are the three great, original, and constituent, orders of every civilized society, from whose revenue that of every other order is ultimately derived. (Smith, 1776)"

Smith had argued that competition would tend to reduce the profit to an 'ordinary or average' rate on the employed capital, and had considered profit at this 'natural' rate as being akin to wages and rent. Such profit was different from wages of management, and appeared in the form of a surplus after taking care of all other payments, out of which 'new capital could be accumulated' (Meek 1962: 297). Profit thus appeared as a distinct category of surplus, apart from rent, while interest was only a 'derivative revenue from it' (Bharadwaj 1978: 17).

1.1.1.2. Value in Production and Value in Exchange: the beginnings

In mercantilist Britain, commercial gains from foreign trade were substantial, owing to the application of a system of colonial trade to ensure some element of monopoly to the parent country. Primarily through this 'exploitation of a dependent colonial system' State-regulated exploitation through 'economic policy..."
of an age of primitive accumulation' had become so important that some Mercantilist writers had treated gains from foreign trade 'as the only form of surplus, and hence as the only source both of accumulation and of State revenue' akin to rent as the exclusive *produit net* of Physiocrats (Dobb 1950: 209). Thus, in the last century of the Mercantilist period in Britain, 'the economic analysis of production was almost always subordinated to the analysis of exchange' (Meek 1951: 31). In contrast, gains from external trade in France were of little economic significance and thus, 'it was possible for the foundations of the Classical analysis, with its emphasis on production [...]’ (Meek 1950: 31–32) to emerge in that country.

Eventually classical analysis had crossed the English Channel, again due to a couple of historical reasons, but not in the Physiocratic form. First, more intense competition in foreign trade had forced British merchants to devote more attention towards reduction of production costs in manufacture, aided by the developments in the industrial techniques. Second, as a distinct and normal category of income, net profit on capital had emerged slowly, which was found to be almost at the same rate per cent on 'capital employed not only in commerce but also in manufacture and agriculture' (Meek 1951: 32). As a result, '[e]conomists gradually began to regard profit as *originating* in the process of production and as merely being *realised* in the act of sale [and] naturally began to seek for the origin of the social surplus in the sphere of production rather than in the sphere of exchange' (Meek 1951: 32; emphasis as in original).

For Smith, labour was differentiated as productive and unproductive—the former assisting in creation of surplus while the latter simply shared it—just like Physiocratic differentiation of classes into productive and sterile, but with the important difference that manufacturing was held as productive like any other similar surplus contributing sector. The productivity of labour as well as the

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20 Turgot had anticipated the equalisation of interest rate (or profit rate) between different activities. See, Brewer (1987)
21 Oft quoted beginning of *An Inquiry into the Nature and Causes of the Wealth of Nations*:

The annual labour of every nation is the fund which originally supplies it with all the necessaries and conveniencies of life which it annually consumes, and which consist always either in the immediate produce of that labour, or in what is purchased with that produce from other nations.

According, therefore, as this produce, or what is purchased with it, bears a greater or smaller proportion to the number of those who are to consume it, the nation will be better or worse supplied with all the necessaries and conveniences for which it has occasion.

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proportion between productive and unproductive labour were argued to be dependent upon the accumulation of capital. The latter's importance also resulted from the possibilities of extension of division of labour. Within such a prospective surplus by productive labour in manufacturing, lay the roots of the existence of industrial profit, which was thus regarded as 'being an income in the nature of a surplus' (Meek 1951: 33). Thus in the Smithian world, social surplus assumed the dual form of rent and profits, unlike the solitary form of rent for the Physiocrats. Profit thus became independent of rent and its continuation did not require regulatory assistance by the state: it was possible even under the competitive conditions.

1.2. Classical Theories of Value

The Smithian assertion of profit as a normal category of income and one of the constituents of social surplus had put the prevailing constructions over value of a commodity, the 'physical cost' theory, into a difficulty. According to it, no surplus came out of production, as the 'value' of what went in and that of produce were identical. Thus, to account for profit within this theory, it was necessary to presume commodities being sold above their 'value'. At the same time, with the emergence of competition, following the development of capitalism, 'economists became increasingly impressed by the fact that the actual prices received for a commodity tended to oscillate around a sort of mean or average price [...]’ (Meek 1951: 34). Thus, '[i]t began to be felt that value ought to be conceived, not as something which a commodity usually sold above, but as something which under competition it tended to sell at' (Meek 1951: 34: emphasis as in original). Clearly, it was not possible for the physical cost theory to consider profit as one of the constituents of value-surplus originating in the production, whose realisation takes place only during the sale of the commodity at the market. Further, for Smith, surplus had become heterogeneous in content unlike for the Physiocrats, for which purpose a price theory of value became a necessity. However, Smith

22 Physiocrats did not require a value theory, in order to conceive rent as the sole constituent of surplus. In the earlier agricultural production, unlike in manufacturing, the ingredients of
was interested more in the 'standard of measurement' for estimation of the values of commodities and of changes in them rather than the cause or rule (i.e. principle) of value or the determination of prices per se (Dobb 1973: 47; Bharadwaj 1978: 21). This 'theory of price' was called 'Adding-up Theory' following Sraffa's description—a summation (merely) of three primary components of price [...] alternately [...] described as a simple Cost of Production Theory: in which guise it has been handed down through the nineteenth century and become known in text-books of the subject' (Dobb 1973: 46).

However, the resonance of the Physiocratic notion of a pre-eminent agricultural surplus remained in Wealth of Nations, as Meek (1951) pointed out: 'It is the surplus produce of the country only, or what is over and above the maintenance of the cultivators, that constitutes the subsistence of the town, which can therefore increase only with the increase of the surplus produce' (Book III).23 In other words, such surplus from country became a necessity for the rest of the society to survive and make progress.24 This fundamental physiological fact pioneered by the Physiocrats shall always remain true, albeit with its own historical specificities. The notion of surplus, in this thesis, rests on this 'objective fact'.

To return to Smith, it is also interesting to find the differences within his treatment of productive powers of labour in agriculture and manufacture:

[...] No equal capital puts into motion a greater quantity of productive labour than that of the farmer. Not only his labouring servants, but his labouring

both input and output were qualitatively very similar, 'so that the creation of the surplus can be plausibly described in real terms without the intervention of a value theory' (Meek 1951: 35; emphasis as in original).

23 Such 'ambiguities' by Smith could also be located in his treatment of rents, profit and wages—they were stated to the original source of value, as well as components of price (Bharadwaj 1989: 14). She (1978: 18, 1989: 14) is of the view that Smith, the 'harmony' economist, had simultaneously followed a number of arguments which can explain his paternity in economics and his 'security' as one of the originators and founder-scholars of the surplus based theories. Dobb (1973: 55) on the other hand, had reminded that Smith's writing took place

[...] in a century when some of the most notable progress in capitalist investment and new productive methods was made in agriculture rather than in industry. His doctrine can be properly understood only as reflection of a period of transition, whose problems essentially consisted in clearing the ground for industrial investment and expansion [...].

24 § 3. In some degree therefore, let the terms of the question be varied, keeping however its principle in view; and with the Chinese state the proposition thus: that part of society only can be considered as productive, whose labour and skill are devoted to the cultivation of the soil, in order to the production of food. (Wakefield, 1804: 2–3; emphasis as in original, words changed from Old English).
cattle, are productive labourers. In agriculture, too, Nature labours along with man; and though her labour costs no expense, its produce has its value, as well as that of the most expensive workmen. The most important operations of agriculture seem intended, [...] as to direct the fertility of Nature towards the production of the plants most profitable to man. [...] Planting and tillage frequently regulate more than they animate the active fertility of Nature; and after all their labour, a great part of the work always remains to be done by her. The labourers and labouring cattle, therefore, employed in agriculture, not only occasion, like the workmen in manufactures, the reproduction of a value equal to their own consumption, or to the capital which employs them, together with its owner's profits, but of a much greater value. (1776, Book II; emphasis added)

Nature's contributions in production, and the obvious visibility of the difference between working time and production time in agriculture, were to influence Marx later.

1.2.1. The Primacy of Factor Incomes: 'overture' to the theories of value

Smith represented a transition from a primarily agricultural society to a developed capitalist economy (Meek 1951: 36). While profit could become independent of rent, the status it enjoyed was similar to that of rent, if not a little less, considering Smith's opinion on the relative productiveness of labour across agriculture and manufacturing. However, historical factors were to play their role, yet again, on the question of the origin of capitalist profit and its relation to the land rent.

While massive increases in productivity and profit in British manufacturing and losses suffered by British commerce due to the Napoleonic wars had played catalytic roles, it was the political struggle between the recipients of rents and profits that had culminated in the passing of the historic Great (or First) Reform Act of 1832 (Representation of the People Act 1832). As per the preamble, this was An Act to amend the representation of the people in England and Wales, that began with the following sentence: 'Whereas it is expedient to take effectual Measures for correcting diverse abuses that have long prevailed in the choice of members to serve in the commons' house of parliament'.

[Its passing] marked the consummation of the victory of the capitalist order in Britain. The question of the origin of profit and the nature of the interdependence between rent and profit began to be regarded as politically significant. If the agricultural surplus was in fact the basic income out of which all the other incomes were ultimately paid, this might be presumptive

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25 Such transition was between a predominantly agricultural society, where land rent is likely to be 'primary and original' category of income, leaving profit as a secondary and derivative category, and developed capitalist economy where profit is more likely to be primary category and land-rent as secondary income (Meek 1951: 36).
evidence in favour of special discriminatory measures protecting agriculture and the recipients of rent [and not to others]. (Meek 1951: 37; emphasis as in original)

The debate on productive and unproductive labour continued in Britain through 'pamphleteering' (Dobb 1973: 65–66; Bharadwaj 1978: 12), followed by passing and repealing of regulations.26 'It was not a question of the classes against the masses, or, of the rich against the poor, but of the land-owning class against the commercial and manufacturing class' which was to influence Ricardo's discussion on value, distribution and accumulation (Bharadwaj 1978: 19).

John Gray in The Essential Principles of the Wealth of Nations (1797), had argued for 'ingenuity and labour of inhabitants exercised upon the fertility of the soil' to be the sole origin for social surplus. Thus, only the agricultural labour was found to be productive. Further, it was argued that the profit outside agriculture originated not in production but in exchange.

[...] The proprietors of land as mere receivers of land rents are not an essential class in society, any more than engravers, statuaries, &c. It is by the constitutional appropriation of the rents of land to the defence of the state, that the receivers of those rents become an essential class in society. By separating the rents of lands from the constitutional purpose of the defence of the state, the receivers of those rents instead of being an essential class, render themselves one of the most unessential and most burdensome classes in society. (Gray 1797: 51; spellings from old English changed)

A response came from Wakefield (1804) in his Essay upon Political Economy which started with questioning the division of the society done by French economists into productive and unproductive.27 While evaluating the doctrines of 'Persians', 'Chinese', Locke, Quesnay, French economists including Turgot, Malthus, Arch-deacon Paley, Xenophon, Aristotle, D'Avenant, Colbert, Steuart, Smith, Necker, Casaux, Hamilton, Wallace, and Canard (1804: fn, 6), he had framed the first question of inquiry: 'Whether labour employed in manufactures be productive?' (Wakefield 1804: 6–7). With appropriate definitions for labour,28

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26 Corn Laws to protect cereal producers in Britain against less expensive import by erecting legal barriers through Importation Act, 1815 and its subsequent repeal through Importation Act, 1846 provided further impetus.

27 How could it be that, simple possession of a property in land, intitles a man to be considered as a productive member of society; [...] [as] by this division, every species of labour employed upon land, as well as every production of the soil, is considered as productive and valuable, though it must be apparent, that articles of the least possible use, not unfrequently engage the labour and occupy the land of the cultivator. (Wakefield 1804: 1–2)

28 Every employment of the time and exercise of the skill or faculties of man.
manufacture,\textsuperscript{29} productive\textsuperscript{30} and surplus value,\textsuperscript{31} the object of interest was set to be the respective processes of 'a previous annihilation' in agriculture and manufacturing. For the cultivator they included the following: 'first, of his own intermediate support, between seed time and harvest; secondly, of the wear of his stock advances (live and dead stock, as cattle for work, implements, sheds, &c); and thirdly, of the seed sown'. For the manufacturer they were 'first, of his own intermediate support between the beginning and completion of the manufacture; secondly, of the wear of his stock advances (tools, machines, buildings, &c.); and thirdly, of the raw material used' (1804: 9–10). Wakefield's conclusion on the sources of surplus was straightforward (1804: 14–15, 28):

[...]

surplus of the manufacturer, whether real or nominal, resolves itself into profits of stock and interest of capital; while that of the cultivator resolves itself into profits of stock and rent of land [...]

and it will go near to prove, that the labour of the manufacturer yields a surplus value.

[...]

To conclude, that rent and interest are equally caused by the labour and ingenuity of man, producing a surplus value, whether employed on land or capital, in agriculture or manufactures.

Wakefield's analysis of the problem through the route of cost and surplus, as per the classical tradition, resulted in a 'theory of value' (Meek 1951: 39). He argued against the possible Physiocratic objections to the productiveness of labour employed in manufacture being only of nominal increase or being only a transfer of produce from one class to other with the assertion that an identical objection could be made in the case of cultivators as well.

[If labour of the cultivator yields] a value, greater than the value or the cost of what he annihilated in order to procure his harvest [...] labour of the manufacturer [...] yields a material, or act, or quality, which will exchange for more, or which is worth more in the estimation of the consumer, [...] and it is contended, that the estimation of the consumer is an evidence to the value of the labour of the manufacturer. (Wakefield 1804: 12–13)

Among the other pamphlets, Britain Independent of Commerce (1807) by William Spence had created quite a furore (Meek 1951: 41). Its long subtitle,\textsuperscript{32}

\textsuperscript{29} Every exercise of human labour upon a natural production, or raw material, either in heightening its original, or annexing to it some foreign properties, or in converting it into some other form.

\textsuperscript{30} Yield or creation of a material thing, or of some property or quality not before in such thing, or so latent, that but for an exertion of labour it would neither have been apparent, nor of use.

\textsuperscript{31} Only such a yield or creation, as shall be in value more than the cost of the labour expended in procuring such yield or creation.

\textsuperscript{32} Proofs, deduced from an investigation into the true causes of the wealth of nations, that our riches, prosperity, and power, are derived from resources inherent in ourselves, and would not be affected, even though our commerce were annihilated.
made obvious the arguments and conclusions. Even if the master-manufacturer may have received a surplus from selling the produce at more than the 'real value' in physical cost terms, and may have accumulated a portion as profits, it was nothing but a transfer and had made no addition to the 'national wealth', echoing Physiocrats once again. In 1808, James Mill had published *Commerce Defended*, with a rather self-evident and provocative sub-title. The chapter 'Consumption', Meek (1951: 41) argued, elucidated the 'main ideas associated with the mature Classical outlook—that production is primary and consumption secondary, that the economic progress of society depends upon the accumulation of capital, and that the only possible source of funds for accumulation is the social surplus'. The attack was based on a class-based analysis, and brought together politics and economics closer than it was before, and that too rather clearly. Two species of 'consumption' were identified: 'one is an absolute destruction of property, and is consumption properly so called; the other is consumption for the sake of reproduction, and might perhaps with more propriety be called *employment*[...]' (Mill 1808: 69; emphasis as in original).

Ricardo's *On the Principles of Political Economy and Taxation* appeared in 1817. 'Chapter 1: On Value', section 1 began with the following heading: '1.1. The value of a commodity, or the quantity of any other commodity for which it will exchange, depends on the relative quantity of labour which is necessary for its production, and not on the greater or less compensation which is paid for that labour' (emphasis as in original). This essentially, broke 'the ties' which still existed between the physical cost and labour cost concepts. A 'theory of value' was born, which was 'free from any bias towards the old physical cost concept, and which was capable of distinguishing between cost and surplus in manufacture as well as in agriculture' (Meek 1951: 47). Its necessity arose from the fact that, even

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33 *An answer to the arguments by which Mr. Spence, Mr. Cobbett, and others, have attempted to prove that commerce is not a source of national wealth.*

34 It is clear then that expenditure, not parsimony, is the province of the class of land proprietors; and that it is upon the due performance of this duty by the class in question, that the production of national wealth depends. And not only does the production of national wealth depend upon the expenditure of the class of land-proprietors, but for the due increase of this wealth, and for the constantly progressive maintenance of the prosperity of the community, it is absolutely requisite that this class should go on progressively increasing its expenditure. It will follow, as a consequence, that in countries constituted as this and those composing the rest of Europe are, the increase of *luxury* is absolutely essential to their necessities. (Mill 1808: 66)
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if production of surplus in agriculture could have been visualised in physical terms, it was not true for manufacture, as for latter inputs and output consisted usually of heterogeneous and different commodities. While it was well established that labour could produce surplus in manufacture, as in agriculture, it could only be visualised in terms of 'value', and 'which required quite a considerable development in the use of abstraction in economic analysis' (Meek 1951: 46). Further, by then, capitalist methods had spread throughout the then Britain and substantial increases in productivity had occurred throughout the economy:

[...] as accumulation came to be made more and more out of profits and less and less out of rents, the idea naturally became current that profits were not just equally important as rents, but somehow superior to them [...] elements akin to rent are found in profit and wages [...] there was nothing sacrosanct about rent and nothing unique about agriculture. (Meek 1951: 46)

1.2.2. Use-value and Exchange-value

[...] Of everything which we possess there are two uses: both belong to the thing as such, but not in the same manner, for one is the proper, and the other the improper or secondary use of it. For example, a shoe is used for wear, and is used for exchange: both are uses of the shoe. He who gives a shoe in exchange for money or food to him who wants one, does indeed use the shoe as a shoe, but this is not its proper or primary purpose, for a shoe is not made to be an object of barter. (Aristotle, 350 BCE: 10)

With these words, the foundation was laid for the difference between use-value and exchange-value (Roll 1938: 34). Aristotle was claimed also to have a 'concept of value' elaborated in Politics and Nicomachean Ethics, but not a labour theory of value (Johnson 1939). Later, with the inheritance of labour theory from Petty and Cantillon, Smith went on with his 'value in use' and 'value in exchange' to develop his own labour theory of value.

35 Johnson (1939) argued that for both Plato and Aristotle, labour contained value but not something that gave value. Aristotle was argued to have also believed 'in labor as a commodity, by including "wage labor" along with "commerce", "usury", and "chrematistic"', with the latter not 'unjustly rendered as "mercantile capitalism"'. True wealth for the Greek thinker, was defined as 'a quantity of tools'. Since slaves were only 'live tools' no labor was necessary to make the tools productive. As they work themselves, wealth was argued to be provided 'by nature herself' and not by πόνος, pain or labour.

Perhaps Aristotle, when he wrote the Politics, and Marx, when he wrote Das Kapital, would have acknowledged that demand is necessary for exchange; yet each would have maintained that there was something on the other side of the equation more fundamental for the creation of value: in the case of the Greek thinker, use; in the case of the German economist, labor (Johnson 1938: 448).
1.2.3. Labour Theory of Value

While the measurement of surplus containing heterogeneous commodities had prompted Smith to envisage a 'price theory', the search was for a stable and invariant standard, for assessment and comparison over time and across nations, prompted by the interest in the real accumulation process determining relative powers of countries (Bharadwaj 1978: 20–21).

[...] As a measure of quantity, such as natural foot, fathom, or handful, which is continually varying in its own country, can never be an accurate measure of the quantity of other things, so a commodity which is itself continually varying in its own value can never be an accurate measure of the value of the other commodities. (Smith 1776, cited in Dobb 1973: 47-48)

Money prices were regarded too fickle, and labour was thought to be the 'real money', the only possible standard.

[...] Equal quantities of labour, at all times and places, may be said to be of equal value to the labourer. In his ordinary state of health, strength, and spirits; in the ordinary degree of his skill and dexterity, he must always lay down the same portion of his ease, his liberty, and his happiness. [...] Labour alone, therefore, never varying in its own value, is alone the ultimate and real standard by which the value of all commodities can at all times and places be estimated and compared. It is their real price; money is their nominal price only.

But though equal quantities of labour are always of equal value to the labourer, yet to the person who employs him they appear sometimes to be of greater, and sometimes of smaller value. He purchases them sometimes with a greater, and sometimes with a smaller quantity of goods, and to him the price of labour seems to vary like that of all other things. It appears to him dear in the one case, and cheap in the other. In reality, however, it is the goods which are cheap in the one case, and dear in the other. (Smith 1776)

This distinction between labour-embodied and labour-commanded were quite clear, (Dobb 1973: 48) and referred to the distinction between the 'amount of labour which the production of a commodity costs' and 'the price at which that labour will exchange in the market'. The latter was to be termed value or price of labour-power by Marx later. Smith's dilemma foreshadowed the split between the 'production cost theories of value' and the 'subjective preference theory of value' which exist to this day in economics' (Patterson 1998).

Bharadwaj (1989: 24) had underscored two specific contributions of Smith to the problem of value. One is his clear formulation of 'natural price', which was 'sufficient to pay the rent of the land, the wages of the labour, and the profits of the stock employed in raising, preparing and bringing it to market, according to their natural rates'. These were 'central prices' around which commodity prices continually gravitated or constantly tended towards. 'Such natural values' then became a term of comparison, or norm, with which all "artificial prices" [...] could
be contrasted and exposed' (Dobb 1973: 43). The second was the distinction maintained between 'natural price' and 'market price', with the latter higher or lower than the former. Natural price was more of a 'theoretical price' compatible with the viable reproduction of the 'natural state', for which all the three basic elements of 'effectual demand', methods of production and wage, were rooted in historical experience.

In the first two editions of Principles (1817 and 1819) the requirement of invariant standard was met by embodied labour, which Bharadwaj (1989: 43) had referred to as a 'simple' labour theory of value.36 However, the third edition (1821) and the unfinished manuscript of 'Absolute Value and Exchangeable Value', contained Ricardo's efforts to modify the labour theory of value in the light of different proportions of means of production to labour in different commodities. One attempt was through the equation relating rate of profit, social product (net of rent) and wage: as long as the latter two were expressed in homogenous commodities (of corn, say) or homogenous magnitudes (of labour, say) the surplus-based theory was facing no difficulty. However, once changes in wage resulted in variations in relative prices, problem of simultaneity appeared. Ricardo could not transcend the difficulties and it was 'left to Marx to restate the problem of transforming labour values into prices of production [...] ' (Bharadwaj 1989: 45).

For Marx, the important questions were explanation of the origin of the surplus itself, and how was it extracted and appropriated in the competitive capitalist

36 In the opening sentences of section vi, Ricardo made obvious the desirable properties of invariable standard:

When commodities varied in relative value, it would be desirable to have the means of ascertaining which of them fell and which rose in real value, and this could be effected only by comparing them one after another with some invariable standard measure of value, which should itself be subject to none of the fluctuations to which other commodities are exposed. Of such a measure it is impossible to be possessed, because there is no commodity which is not itself exposed to the same variations as the things, the value of which is to be ascertained; that is, there is none which is not subject to require more or less labour for its production. (Ricardo 1817)

Dobb (1973: 82) commented that 'he seems to have accepted the view that invariability in a standard was not only impossible to find in practice but was impossible in principle'. He had credited Sraffa for revealing the true nature of the problem that Ricardo had. '[H]is primary concern was with the effect of rise or fall of wages—with 'change' rather than with 'difference'. In the words of Sraffa in Ricardo (2005: xlvii–xlxi),

[...] the problem of value which interested Ricardo was how to find a measure of value which would be invariant to changes in the division of the product; for, if a rise or fall of wages by itself brought about a change in the magnitude of the social product, it would be hard to determine accurately the effect on profits.
economy.\textsuperscript{37} Holding that competitive prices were the specific form of exchange value had taken historically under competitive capitalism, or even under equivalent competitive exchange, surplus, Marx argued, was generated and appropriated in the process of production through the exploitation of wage labour, while it was realised only in the sphere of circulation. Reconciliation between surplus value and the 'law of value' in his own framework followed the crucial distinction between labour and labour-power.\textsuperscript{38} While this issue will return later, the approach may be indicated here. In \textit{Capital}, labour-power was defined as the 'energy transferred to a human organism by means of nourishing matter' and was 'the aggregate of those mental and physical capabilities existing in a human being which he exercises whenever he produces a use-value of any description'. As Dobb had put it,

\begin{quote}
[T]he 'nourishing matter' needed to replace the energy used-up in work was the material input into human labour; and the possibility and dimensions of surplus-value depended upon the value of the former being less than the value 'created' as output by the labour it sustained. The difference between the two he spoke of as the difference between 'necessary labour-time' (the input) and the total labour-time actually expended in production. (Dobb 1973: 151; emphasis added)
\end{quote}

Nature of inquiry in the present thesis rests on this difference between the value of the input and the value created, measured in energy terms.\textsuperscript{39} This is in line with the 'classical' approach of inquiry into socio-economic problems of the day, which in our case concern the 'unsustainability' of the agricultural operations.

Classical theories held that a number of complex factors influence exchange value of a commodity in actual practice. While the prices of production were viewed as 'a highly simplified way of approaching the problem of competitive value through a scheme of abstraction', the 'predominant influence of cost of production in the determination of the value of commodities' remained as the 'fundamental factor' [Pierro Sraffa, 1926, 'The Laws of Returns under Competitive Conditions', \textit{Economic Journal}, 36 (144): 535–50 quoted in Bharadwaj (1978: 66)]. Thus 'it did not include \textit{within the explanation of value} any theory, explicitly or

\textsuperscript{37} Dobb (1973: 141) had evaluated Marx as the one who 'has been more variously estimated, as well as more misinterpreted, than almost any other economist of note'.

\textsuperscript{38} Marx's theory of surplus value also included the questions on increasing its rate—through lengthening of the working day (absolute surplus value) or reduction of 'necessary labour time' as a proportion of total labour time (relative surplus value) (Dobb 1973: 154).

\textsuperscript{39} For inputs, material input to human and animal labour as well as material consumption and depreciation in stock have been converted into their corresponding energy (or embodied energy) values. Calculation of the calorie value of the selected food crops and their by-products is used to estimate the value created.
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implicitly, of what determines social consumption and social output, its level or composition, taking these as provisionally the data of the problem, within historically given conditions' (Bharadwaj 1978: 66; emphasis as in original).

Indeed, two features of classical approach weigh in favour of its adoption for addressing the research question at hand, besides the advantages of 'openness' that it offers towards incorporating a number of 'historical and social influences'. One, the separation of quantities from prices that allows examining one without the other, and two, its view of production as a circular process, in contrast to the given factor endowments approach of neoclassical theory. While the method of energy balance analysis shall be discussed in detail later, its basic feature remained as a cost of production theory of value, and it enjoys an obvious similarity with the embodied labour theory of value. One may reiterate the central analytical features of classical political economy before establishing the link between classical approach and the energy analysis in the following section.

[...] The classical theorists had sought the determinants of value in the material conditions of production, later termed as 'costs of production' (Pierro Sraffa pointed out to me that the term 'cost of production' came into vogue only at a later stage when a distinction was made between exchange value (price) and cost. In earlier theories, value was used synonymously to represent 'costs' in production). While the notion of 'costs' itself gradually changed [...] and various components of costs were variously analysed, still one may say that it was the 'objective' material basis of production that determined the value of products. The labour theory of value was initially constructed on the implicit premise that all means of production were reducible to labour directly or indirectly. [...] Under whatever specific form values were discussed—whether as labour values or prices of production—the basis of value was located firmly in the sphere of production and costs reckoned in terms of 'productive consumption' (material inputs plus wage goods) essential to support the productive process. This implied, as a method, a reliance on objective conditions. (Bharadwaj 1978: 30)
1.3. Classical Approach, Standard Commodity and Embodied Energy
In 1960, Pierro Sraffa had published 'a short work' of less than one hundred pages, which took him 'a rather disproportionate length of time' of more than 30 years to complete (Sraffa 1960: vi). This 'slender but classic' (Dobb 1973: 248) work had revived the classical approach, in contrast to the marginalists', in vogue since 1870s. The 'investigation' was 'concerned exclusively with such properties of an economic system as do not depend on changes in the scale of production or in the proportions of "factors"' (Sraffa 1960: v). While marginalists' approach required attention focussed on change, the system under study by Sraffa was where 'day after day, production continued unchanged in those respects' and where 'the marginal product of a factor (or alternatively the marginal cost of a product) would not merely be hard to find—it just would not be there to be found' (Sraffa 1960: v).

The property of capital as 'an independent quantitative entity' which could be 'substituted in defined amounts for other factors of production' in particular, and the entire notion of 'production function' in general was questioned (Dobb 1973: 252). In Sraffa's framework of 'dated labour', the cost and final price of a commodity was 'conceived as the summation of a vertical series of stages of production spread out backwards in time, each consisting of a labour-input plus commodity-inputs (machines, raw materials, components) that are products of some earlier stage; each with its labour-input having its attached date in the vertical series' (Dobb 1973: 253).

In algebraic terms, Sraffa's system can be depicted as a corollary of the Dmitriev's equation with substitution of labour terms by quantities of wage goods (Dobb 1973: 259). In particular, 'reduction to dated quantities of labour' equation of Sraffa was interpreted by Dobb (1973: 260) as the one where prices were derived from the description of 'production in terms of labour expenditures per unit of output, with a time period attached to these expenditures'.

England (1986), and many others, had pointed out that Sraffa's analysis of joint production is amenable to include waste emission and environmental protection. It is the similarity between the assumptions made by the neo-Ricardians on the one hand and those of the ecological economists, that had resulted in such a
conclusion. Among others, they included viewing production as a circular process rather than a linear flow from 'inputs' to outputs, and its link to the creation of surplus. Indeed, for the latter, this framework 'encourages one to theorize about the reproduction of economic systems and the particular requirements which must be satisfied if reproduction is to occur' (England 1986: 233; emphasis as in original).40

It is not just with regard to the neo-Ricardians; research in the last thirty years has also established similarities in the analytical approach between the Marxian framework and ecological economics. Gowdy (1984) in one such early attempt.41 Further, it had asserted that in Marxian terms the social relations of production could influence the efficiency of capital by speeding up the entropic process. In fact, Marx's critique of capitalist agriculture for leading to premature exhaustion of the land followed this argument.42

Neo-Ricardian approaches had received much attention following Sraffa's work. In it, exchange values of any particular commodity, in relationship with every other commodity in the economy were to be entirely determined by the sociotechnical conditions of production. Clearly subjective tastes and preferences of the consumer had no role, as was the case in Classical approaches. However, their primary contribution was in arguing that subject to certain conditions, test of 'invariable standard' could be fulfilled by any commodity: even energy was a serious candidate.

(...) With this theoretical tour de force in hand, Neo-Ricardian's began to challenge the Marxian analysis, arguing that labor [...] is only one of many inputs into the production of commodities. [...] The fundamental challenge [...] is their contention that the value of any commodity can be expressed as

40 For a critique over such an interpretation of Sraffa as an ecologist, see Patterson (1998).
41 Wealth consists of use values which may arise from nature:
Labor is not the source of all wealth. Nature is just as much the source of use values (and it is surely of such that material wealth consists! as labor, which itself is only the manifestation of a force of nature, human labor power. [...] And insofar as man from the beginning behaves toward nature, the primary source of all instruments and subjects of labor, as an owner, treats her as belonging to him, his labor becomes the source of use values, therefore also of wealth (Marx 1970).
On the other hand, exchange value arises from the process of production, specifically from direct or indirect human labor power. Thus, while labor becomes the source of all value in exchange, nature is the ultimate source of wealth (value in use).
42 Briefly put, in Marx's formulation, premature exhaustion of the soil occurs due to economic disincentives to maintaining long-lived capital investments. While rising cost of raw materials depresses the rate of profit through increase in resource exhaustion, in reality the 'marginal cost' of a non-renewable resource happens to be only the marginal cost of extraction and not production, thus creating a surplus for the producer (Gowdy 1984).
its exchange ratio to any "standard" or "basic" commodity, not only in terms of its required labor content. (Judson 1989: 262)

Judson (1989: 261) argued that it is only since 1985 that 'concepts of energy and entropy have made significant inroads into economic thought'. Arguably, this took so long despite efforts by Georgescu-roegen to replace the 'logo for old economics [of] [...] frictionless Newtonian pendulum which swings forever' with that of 'an hourglass whose sands run downward as the arrow of time advances, and an irreversible process that admits of no permanently renewable steady state for maintainable economic consumption' (Samuelson 1999: xiv; emphasis as in original).

Judson (1989: 262) had found 'ecoenergetics' to be closer to the classical approach to economics rather than the neo-classical one. Further, Christensen had pointed that the central weakness of the neo-classical production theory lay in its neglect of material and energy resources within the primary factors.

Parallel to the Sraffian revolution, developments in the modern ecology (to be discussed in the next section) had put forward the importance of energy 'content' of the commodity (expressed as the amount of energy that can be released from it in combustion or behaviour), and the energy cost of production of a commodity (expressed as the energy used up in the manufacture of the good). Added was a third perspective, that had argued for the energy input or content as an important

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43 '[..] Tendency of energy toward a universal equilibrium is called dispersion of energy, or according to Clausius's terminology, Entropy. This last term expresses the quantity of energy transformed that cannot undergo additional subsequent transformations. These two principles of Clausius derive from it: The energy of the universe is constant. The entropy of the universe tends towards a maximum' (Fodolinsky 1881/2004: 62; emphasis as in original).

44 This term has the same qualifications as Dobb (1973: 248). There are well-recognized criticisms on the assumptions behind such theoretical formulation (Söderbaum 1999; Burkett 2003/04; Martinez-alier 1997: 32), which is beyond the scope of this work to address.

Judson (1989) identified three dimensions that are important in theories of value which resulted in the confusion between classical and neoclassical economic theories:

- (1) macro- versus micro-level analysis—the central conflict in this respect is over the question as to 'whether the individual or the society is made the starting point of economics'. It is manifested for example, between marginal utility perspective and the embodied labour perspective on value
- (2) objective versus subjective analysis—debate over this question is classic and continued ad infinitum, between, anthropocentric, eocentric and even anthromorphic perspectives, and
- (3) dynamic versus static analysis—this can be best illustrated with the contrasting notions of efficiency: in one it is the ratio of output to input without any consideration to time while in the other it is the output per unit of time, without taking into account the inputs (Mayumi 2001b).

factor in determining value, while maintaining that it is only one of many possible
inputs. It is important to note that all the three approaches had been termed
under ‘energy theory of value’, and just like the phrase, ‘classicalist approaches to
value’ there lay crucial differences among them, which often resulted in
unnecessary and avoidable confusion.

Most famous proponent of the first ‘school of thought’ was ecologist H T Odum,
who had worked tirelessly in establishing energy values of various aspects of the
biosphere, including biotic and abiotic resources and ecosystem services. Odum’s
‘maximum power principle’ argued that eventually systems which transform
energy at the most optimal rate would out-compete other systems and therefore
will survive. His ‘energy theory of value’ was based on the idea of EMERGY, a
measure of the value of a commodity in terms of the amount of energy required to
produce it (Patterson 1998).\footnote{Chen et al. (2006) had performed an EMERGY analysis of Chinese agriculture, while
Martin et al. (2006) did the same for three agricultural systems in US and Mexico.} Most of the criticism over energy analysis from the
economists had originated from the construction of this particular version of
‘energy theory of value’ (Slesser 1978: 3). Arguments from critics like Georcescu­
roegen, Herman Daly and Kenneth Boulding ranged from the non-homogeneity
of matter in contrast to the homogenous energy, to the ignorance of factors in the
economic system ‘other’ than the energy constraints (Judson 1989; Patterson

For the purposes of this work, the second approach assumes more importance.
Here, the energy ‘content’ of a commodity is analysed for arriving at the total cost
of production in energy terms. In other words, such an embodied energy theory of
value is essentially a cost of production theory, where all costs are carried back to
the primary input, the only ‘scarce’ factor of production, the solar energy required
to produce them, with labour, manufactured capital, and natural capital as
‘intermediate’ inputs (Slesser 1977: 259; Costanza 1980: 1224; Cleveland 1987;
Farber et al. 2002: 382–383). However, there exist important differences over
the purpose of this exercise.

One strand of thought, mainly from some of the ecological economists, argued
that the energy use intensity and money use intensity could be compared, which
was just a short step before treating energy values as the ‘values in exchange’
(price). Indeed a few had claimed this approach to be a close parallel of neo-Ricardian labour-embodied theory of value with energy replacing labour as the primary costs of production (Farber et al. 2002, for example). For obvious reasons, there had been a number of arguments opposing such an assertion.

Primacy of energy as an input was criticised for the presumption about the reproducibility of the other factors in terms of pure energetics (Burkett 2003: 139). Further, eco-Sraffians argued that production and monetary exchange values depended on labour, resources and environmental services as well. Indeed, ecological economists like Martinez-alier had argued against ascribing value to energy or other 'primary input': there may not be any 'general theory of value'. Burkett (2003: fn 5) commented that following Sraffian framework but rejection of energy theory of value implied that 'composition of the standard commodity cannot plausibly be expressed in pure energy terms, given the material (physical, chemical and biological) differentiation of the production system'. Certainly, energy can serve as an ordinary standard of measure, but not as a 'standard commodity' which would be invariant to the distributional shifts between wages and profits.

The other strand, which consisted of mainly ecologists, thermodynamists, biologists, and energy analysts, had placed energy analysis as a tool for supplementing economic analysis in policymaking. The debate that took place among economists and energy analysts, on the appropriateness, applicability and usefulness of energy analysis in US public policy is illustrative in this regard.47

The third approach took the valuation exercise to the furthest, to the point of suggesting that energy intensities determined even the 'value' of biological components in an ecosystem and just not the economic components (for example, Hannon, Costanza and Herenden 1986).

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47 It was apparently motivated by the 'loss' of hegemonic position in the public policy decision-making that economists had enjoyed. Context was the Section 5, Non-Nuclear Energy Research and Development Act [1974] of US stated that 'potential for production of net energy by the proposed technology at the stage of commercial application shall be analysed and considered in evaluating proposals'. H Odum, an influential and notable Energy Analyst was instrumental in getting this law passed in US Congress (Siesser 1978: 6). See, Gulliland (1975) and Huettner (1976) for energy analysts' and mainstream economists' viewpoints respectively.
Introduction

At the same time, it is worth stating the position of the majority of energy analysts on the question of energy theory of value.

[...] [W]e do not subscribe to any 'energy theory of value'. Our approach while resting on same scientific principles [...] aims to provide description, not evaluation [...]. Logically there is no way that descriptions of what is can be used to deduce what ought to be done. The decision about what to do involves a value judgment and, to be clear, this should be explicitly separated from the description of what is. (Chapman and Roberts, 1983; emphasis as in citation)\(^4\)

Martinez-alier (1987: 147–8, 233) had argued that an energy theory of value might not mean return to the 'energetic dogma' that may force the economic planner to 'minimize the dissipation of energy to maximize the flow of energy utilized', but may also eliminate the differences in valuation between renewable, non-renewable and slowly renewable resources. At the same time, as prices, calories or production time, all satisfy the commensurability requirements; such a theory may enable us to compare the number of years taken to produce geologically equivalent calories of coal or oil as in the total world annual harvest.

Limitations of energy theory of value are many. First, it is related to the reverse translation from energy equivalent to matter in practice (the non-homogeneity problem referred earlier). Some of the factors or materials are non-substitutable, which however are of absolute necessity. On the other hand, different forms of energy are largely substitutable. Secondly, within the energy theory, in the realisation of value, exchange processes had not been incorporated. For example, 'can the value of nonessential luxury commodities be determined by their energy cost of production?' (Judson 1989: 269).\(^4\) This problem is particularly manifested in economic states with surplus that requires distribution. Third, embodied energy theory had been found to be with a lack of focus. Fourth, energy theory is yet to find an acceptable way to handle capital. To be more precise, whether the straight-line method of depreciation is more applicable or a gradual depreciation of energy efficiency is more apt, remain to this day an issue that is yet to be resolved.\(^5\) Fifth and finally, relationship between energy quality,

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\(^5\) Elsewhere, Judson (1989: 274) elaborated the difference between 'basic' and 'non-basic' sectors as follows, which is different from Sraffa: while the non-basic sector is dependent upon the surplus of the basis sector, be it energy or money terms, system of valuation of non-basic goods are unlikely to reflect their cost of production. For example, 'value' of a recreational area through embodied energy.

\(^5\) Also, see, Hannon et al. (1986: 398) that compared attempts by Sraffa and Samuelson on present value of the historic costs in economic systems with the time cost of capital.
technological change and monetary value are far from being addressed satisfactorily. Indeed, energy quality is a major factor in energy use, and such effects are ignored in the homogeneity assumption of much empirical work (Judson 1989).

Norum (1983: 9) argued that, following 'energy as a measure of value' criterion might also result in unreasonable decisions. Consider, for example, the possibility of energy value for input of labour. It follows that worker's demand for goods and services are to be met with energy, given the general level of energy use in society. Now, with rise in use of fuel, value will rise in relation to energy. It follows then that the 'optimal' choice between inputs of labour and fuels will result in substitution of labour by fuel, 'independent of resource depletion and rate of unemployment'!

In response to Duhring's arguments linking energy with value in a rather crude manner, Engels' response was noteworthy in this regard:

[... ] In so far as there is a meaning in this, it is: The value of a product of labour is determined by the labour-time necessary for its production; [.....] It is simply wrong to say that the dimensions in which anyone invests his energies in anything (to keep to the bombastic style) is the immediate determining cause of value and of the magnitude of value. In the first place, it depends on what thing the energy is put into, and secondly, how the energy is put into it. If someone makes a thing which has no use-value for other people, his whole energy does not produce an atom of value; and if he is siff-necked enough to produce by hand an object which a machine produces twenty times cheaper, nineteen-twentieths of the energy he put into it produces neither value in general nor any particular magnitude of value. (Engels 1947)
1.4. Rise of the Energetics—ecological, social, and agricultural

Ecology had a history, even before it had a name, argued Worster (1994: x). It took one hundred more years to enter into the vernacular, 'but the idea of ecology is much older than the name'. In the eighteenth century, it had emerged as a more comprehensive way of looking at the earth's 'web of life' as an interacting whole.\(^{51}\) German biologist and philosopher Ernst Haeckel, a disciple of Charles Darwin, 'the busiest name-maker of his time' in 1866 had suggested Oecologie, to

[...] give a semblance of order to a scientific word that was splitting off into many different line of enquiry [...]. In the broadest sense it was to be the study of all the environmental conditions of existence, or, as his translator later put it, "the science of the relations of living organisms to the external world, their habitat, customs, energies, parasites, etc." (Worster 1994: 192)

The new word was to share the same root as the older word 'economy', with the original meaning of family household and its daily operations and maintenance. Oecologie too was thought to denote living organisms of the earth constituting a single economic unit, like a family or household. 'So if “ecology” at root means the study or science of the oikos and 'economy' means its management, then there would seem to be good reason to see ecology and economy as mutually dependent allies' (Hayward 1994: 91). Indeed, before the International Botanical Congress had given the modern spelling 'ecology' in 1893, biologists were using the phrase 'economy of nature' instead.\(^{52}\) The common root between the disciplines was to result in the adoption of economic concepts in ecology, that was carried forward through parallel contributions from ecologists and economists towards the development of 'bio-economics'. The concept of Metabolism, the 'star', to analyse the human society—nature interactions, relationships and exchanges, with transdisciplinary recognition, acceptance and approval, is the result of such efforts.

By the early twentieth century, contours of the terrain of 'ecology' were quite clear: its raison d'être was the social relations of the natural world—'the science of the development of communities' (Worster 1994: 204). This withstood the test

\(^{51}\) In contrast, at present it has achieved a cult status: it serves as the basis for international regulations on combating climate change, it has carved out a space within the spectrum of political ideologies as well as within the public policy, it has motivated 'new' social movements across the world—its ‘mainstreaming’ is complete, unlike gender, race/ethnicity, caste, children, or disability.

\(^{52}\) Worster (1994) dwelled at length on the changing nature of this phrase throughout the book, as well as the word. See, pp. 192–204, for the interdisciplinary history of 'ecology'.

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of time and gained acceptance across disciplines. In the ecologist's description, an individual became the fundamental unit of populations, communities, ecosystems and biomes. Essential to the understanding of the study was 'how they obtain their energy and nutrients', and a consideration of 'how these are allocated to maintenance, growth and reproduction'. This was an approach quite identical to that of economics (Chapman and Reiss 1995). 'Metabolic rate', 'energy budget', 'assimilative efficiency', 'production', 'growth efficiency', 'distribution' became its important terms, with meanings very similar to those in economics. There were definite historical reasons for this convergence of the two disciplines, apart from sharing the common root in the concepts and methods, cutting across the artificial disciplinary boundaries and chauvinisms, to extend a holistic, rigorous and appropriate treatment of the human society—nature relationship.

1.4.1. Idolising the Nature and the 'Ideal' Nature: idols and ideas in ecology
The end of nineteenth century and the beginning of the twentieth century had been exciting times for science: both for older ones like physics, and chemistry and even for the new field of ecology. It was primarily the Anglo-Americans who had carried out developments in the various aspects of ecology. In Britain, it was the Scots, William and Robert Smith, Glasgow biologist Patrick Geddes (who studied with T H Huxley) and Oxford ecologist A G Tansley and in America it was Henry Chandler Cowles of the University of Chicago and Frederic Clements of the University of Nebraska (Worster 1994).

53 A popular textbook begins as:
Ecology is the study of organisms in relation to the surroundings in which they live. These surroundings are called the environment of the organism. This environment is made up to many different components, including other living organisms and their effects, and purely physical features such as the climate and soil type (Chapman and Reiss 1995).

54 See, for example, Bukharin's energetics, in 1.4.2.4 below.
55 The important fact is that the discovery of the Entropy Law brought the downfall of the mechanistic dogma of Classical physics which held that everything which happens in any phenomenal domain whatsoever consists of locomotion alone and, hence, there is no irrecoverable change in nature. It is precisely because this law proclaims the existence of such a change that before too long some students perceived the intimate connection with the phenomena peculiar to living structures. By now, no one would deny that the economy of biological processes is governed by the Entropy Law, not by laws of mechanics (Georgescu-roegen 1971: preface).
1.4.1.1. Monoclimax Thesis

In 1896, Cowles had applied Eugen Warming's 'model of succession' and climax formation to the vegetation growing in Lake Michigan, and incorporated the 'monoclimax' thesis. In 1890, Clements was joined with Roscoe Pound, both as assistants to work under Charles Bessey, at Nebraska. Clements' central contribution lay in identifying the ecological succession in the plant communities and the organismic character of the plant formation: 'Change upon change became the inescapable principle of Clements' science' (Worster 1994: 209–10). His notion of a 'vaguely climax stage', was based on his argument that, nature's course, is a steady flow towards stability that could be 'exactly' plotted by a scientist. Such notion of 'a relatively permanent equilibrium with the surrounding conditions capable of perpetuating themselves forever' was identical to that of Cowles (Worster 1994: 210). This thesis had brought modern ecology in convergence with the organismic philosophy. In this view, competition, within the natural world, was essential for growth, for progress to achieve the full communal state. The idea was to remain until challenged by the 'age of new ecology', roughly quarter of a century later.

Clements' collaboration in 1939 with Victor Shelford had resulted in the development of 'bio-ecology', that had brought two sub-disciplines of ecology closer to each other. However, a much more important problem was waiting to be addressed by the ecologists: that of presence or influence of humans, which had remained hitherto neglected (Worster 1994: 217).

Meanwhile similarities became more visible between the succession in the plants in a habitat with that of the human society, namely, of pioneering and settlement. In 1893, Frederick Jackson, a historian from Wisconsin, identified the then

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56 'All stages of their [dunes] life-history may be seen; the beginning, the climax, the destruction' (Cowles 1899: 195). Cowles, did not publish much beyond the 1899 article, and disappeared into oblivion; yet, many of his students became leaders in the field—a universal trait of a 'proverbial solitary and self-reliant pathfinder' (Worster 1994: 208).
57 Pound had left for Harvard to study law and then become an authority of sociological jurisprudence. The other biologist turned sociologist was Herbert Spencer. For Spencer's ecological ideas, see, Worster (1994: 212–4).
58 According to the classical ecological theory of Cowles and Clements, the succession stops when the 'sere' arrives at an equilibrium or steady state with the physical and biotic environment. Barring major disturbances, it will persist indefinitely. The end point of succession is called climax. Sere is a term coined by Clements to denote a system of developmental stages that starts with a primitive and inherently unbalanced plant assemblage and finishes with a complex of relatively permanent equilibrium (Worster 1994: 211). This is akin to the notion of 'steady-state' in economics, or physics.
westward moving pioneers as *the* process in forming the national character of the
United States. Such ecology of pioneering became the dominant ethos of the day
and was in line with the evolution of American society at the 'frontier'. This
convergence of ecology and history resulted in an irony. At the frontier, where the
biotic community was to 'climax' and a mature complex civilization was to
emerge, '[...] the two processes of development were fated to meet, it seemed, in
irreconcilable conflict. One would have to give way to the other; it was not
possible to have both a climax state of vegetation and a highly developed human
culture on the same territory' (Worster 1994: 219).

When the 'invading society seeking homes, wealth, and empire' with axe and rifle,
finally entered 'the grassland', the last of the American West, the result was both a
social and ecological disaster—the Dust Bowl of the 1930s. Henceforth, 'man'
could not be left out of textbooks and models in ecology.

The pioneers and homesteaders had literally prepared the soil for this enormity.59
Impact was equally gigantic:60 forced migration,61 poverty,62 and soil erosion.63
While there were definite agro-ecological reasons for the Dust Bowl, couple of
socio-economic ones had also contributed.64 'Not drought but the machine drove
most of these farmers from the land, but perhaps it was easier on their pride to
blame the misfortune on nature' (Worster 1994: 225). The Sodbuster,
representing the environmental ethic of conquest, arguably, gave birth to the 'Dust Bowl refugees'.

Further, with patriotic appeals from the US President to supply wheat to the European allies to win the First World War, coupled with a promising market price, mass production could reach the plains. Great Plains Committee (1936) in its report had concluded, '[a]fter fifty years of being hailed for his heroic exploits, the sodbuster had become a menace to the nation' (quoted in Worster 1994: 230). It categorically blamed the imposition of a system of agriculture unsuitable for the region, and called the disaster wholly manmade. However new dilemmas were to appear in the public policy soon.

1.4.1.2. Anti-climax and Anthropogenic Climax

For reasons of anti-technology implications of Clements' thesis as well as for purely scientific reasons, 'anti-climax' arguments began to appear in the 1930s. The 'carefully orchestrated, precise succession to the climax state' was to be challenged. For A G Tansley of Oxford, the distinctly discomforting issue was to visualize man as a disrupter of nature.

[...] It is obvious that modern civilized man upsets the 'natural' ecosystems or 'biotic communities' on a very large scale. But it would be difficult, not to say impossible, to draw a natural line between the activities of the human tribes which presumably fitted into and formed parts of 'biotic communities' and the destructive human activities of the modern world. Is man part of 'nature' or not? Can his existence be harmonized with the concept of 'complex organism'? (Tansley 1935: 303)

This new climax was to be termed 'anthropogenic' representing a major clash of environmental values, which was waiting to happen in any case. Clements' system of inflexible, monolithic 'sere order' was not always followed by nature. In addition, in the American consciousness, the idea of 'designating nature as a foe to be vanquished and a redeemer to be praised' and that of a wild, untrammelled

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65 Steel plough was his ammunition, with which dense root masses could be removed. Native sod, on the other hand, was the protector against strong wind and drought. Ill-advised practices of ploughing long straight furrows leaving large field completely bereft of any vegetation and planting a single cash crop replacing the diverse plant life had ignored the basic biological fact that soil erosion results from sickness of the vegetation and not from the sickness of the soil (Worster 1994: 226–30).

66 'Nature has established a balance in the Great Plains by what in human terms would be called the method of trial and error. The white man has disturbed this balance; he must restore it or devise a new one of his own'. (Worster 1994).

67 'Sere' was a term meant to imply a system of developmental stages which began with a 'primitive, inherently unbalanced plant assemblage' and finishes with a 'complex formation in relatively permanent equilibrium' with its environment, which was capable of perpetuating itself forever (Worster 1994: 210).
nature were just too strong, far more than in the European one (Worster 1994: 241). Tansley on the other hand, could make the distinction between Europe and America over the civilization’s impact on natural succession.

[...]

Tansley did not want to accept any climax achieved by purely natural processes as an ideal for man to respect and follow. His concern was not to reestablish man as a part of nature, but to put down the threat to the legitimacy of human empire posed by the natural climax theory. If Tansley was right and there were no meaningful differences between the balance achieved by nature and that contrived by man—if the two systems were at least equals in quality and performance—then what reasonable objection could there be to man’s rule over the biological community, or to the further extension of his empire? (Worster 1994: 241)

In other words, Tansley’s argument was in favour of the removal of ecology as a ‘scientific check on man’s aggrandizing growth’—with the removal of Clements’ thesis, there was to be no exterior model to serve as the benchmark for a scientific evaluation. In 1956, with the arrival of James Malin, of University of Kansas, the foremost scholar on the history of grassland, ‘anti-climax’ thesis had received a major boost. Malin had already written in 1953, that ‘[t]he conventional or traditional concept of the state of nature must be abandoned—that mythical, idealized condition, in which natural forces, biological and physical, were supposed to exist in a state of virtual equilibrium, undisturbed by man’ (quoted in Worster 1994: 242–3).

For him, it was the modern agriculture that had lent a stabilizing hand towards a ‘reign of order, peace, and harmony’, given the fact that dust storms had always been a ‘natural phenomenon’ in the Great Plains, with documented evidence since 1830, and most of them happened before the arrival of sodbuster. Interestingly, Malin had argued that the very process of wind erosion had been responsible for building a rich and fertile soil. Without the layering, removal of a foot or two of topsoil made no difference; indeed, it was a gift at the location of its deposit. Malin also refused to be hedged by ecological laws: ‘To obey rather than conquer nature was a surrender [...] to the chain of determinism. [...] It is man, not nature, Malin believed, who creates norms and values’ (Worster 1994: 246). Despite challenges from Malin, however, Climax thesis, had remained in vogue, without making it the final ‘truth’. Nevertheless, the idea of ‘steady-state’ equilibrium in

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69 (Succession-climax model [...] is inextricably wrapped up in those muddled, subjective things called human values. Probably there is no final or compelling reply to the question of whether the climax ever existed or not, or at least no answer that
nature without ‘disturbance’ from man became passé at the end of this debate: the question was how to make economic progress that required natural resources through methods which are economically as well as ecologically sound.

1.4.2. Convergence of Economics with Ecology

The view that nature works through the economic principles of production, trade and consumption, was pioneered by Hermann Reinheimer. In his view, organisms were considered as ‘economic persons’, and nature was argued to be having a refined division of labour to ensure ‘ever-increasing efficiency [in] the production and storage of energies that go to sustain and to help advance life, to produce a maximum of organic and social utilities with a minimum organic cost’ (quoted in Worster 1994: 251). It was promoting cooperation rather than competition, at odds with Darwinian biology, or with the laissez-faire capitalists. Nature was looked at through a different lens by this ‘new ecology’: of ‘the forms, processes, and values of the modern economic order as shaped by technology’. (Worster 1994: 293).

1.4.2.1. ‘The Economy of Nature’: ‘new ecology’ of productivity and efficiency

Worster (1994) pointed out three important features of the modern economic system that the late-twentieth century ‘new ecology’ was to ape: cooperation among the economic agents, without which the system does not simply function; second, importance of productivity and efficiency as human goals; and third, development of the managerial ethos.

In 1927, a Cambridge University zoologist, Charles Elton, had published Animal Ecology (Chicago: University of Chicago Press), that brought together the existing knowledge in ecology to a new model of community, through an approach which had more to do with structure and functions rather than the dynamics. This was in line with the then emerging structural functionalism across social sciences, in place of the evolutionary or historical approaches.

Elton’s ‘bio-economics’ was given a new and definite direction by Tansley (1935). The latter had argued for treating the ‘whole’ through a reductive analysis, where

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Science alone can give for all time. This issue of the climax is enduring conundrum.
(Worster 1994: 249-50)

'the basic units of nature' could be isolated in such a manner that a researcher aware of all the properties of each component could accurately predict the result, like any 'mature science'.

Tansley used the concept of ecosystem rather than community, which was argued to be 'misleading'. In this approach, all relations among organisms in the ecosystem were described in terms of purely material exchange of energy and of such chemical substances such as water, phosphorus, nitrogen, and other nutrients that are the constituents of 'food'. This apparently reductive yet more inclusive concept brought together both living and non-living substances into a common ordering of material resources.

Such focus on the energy flow in the ecosystem, announced the coming of 'age of ecology' as an adjunct of physical science, with its parentage to modern thermodynamic physics, and not biology (Worster 1994: 302). Quantification of energy flow at every point of the progress of an ecosystem was certainly a giant step, especially in line with the agronomic and industrial view of nature as a storehouse of exploitable material resources. Natural scientist Elton was joined by social scientist Nicholas Georgescu-roegen a few decades later with a combination of evolutionary biology, conventional economics and thermodynamics to establish the 'new' discipline of bio-economics (Miernyk 1999: 69).

In 1926, Edgar Nelson Transeau, had attempted to calculate the amount of solar energy accumulated and used towards production of crops in one field at Illinois during one particular season. 'What is the natural energy cost of agriculture, he wondered, and how efficiently is it used in the production process?' (Worster 1994: 304). As per his calculation, the percentage of total energy 'fixed' in the gross output of corn was extremely low.

In 1940, Chancey Juday had calculated the 'physical and biological energy budget(s)' of a natural lake in Minnesota. His calculations involved energy spent

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71 At the same time, such energetic reductionism had been questioned towards the development of bio-economics (Punti 1988: 79). As a possible way, it was suggested that to change some methods and concepts in energy analysis, and combine it with the study of the social relations, notably, human labour energetics. This thesis has done exactly the latter.

72 For Tansley, plants and animals in a locale may not be part of a genuine community due to absence of any psychic bond and thus a true social order (Worster 1994: 301).
and invested in the form of biomass at each level of the ecosystem. In particular, calculations were done for 'total quantity of stored and accumulated energy in the form of dry organic matter in the annual crop of plants and animals', and total energy value of the annual crop on the basis of the energy equivalents of various classes of organic matter. On the question of comparison of efficiency of nature's crop with that by man for utilizing energy, he concluded that the concerned lake

(...) was not a very efficient manufacturer of biological products in so far as utilizing the annual supply of solar and sky radiation is concerned; on the other hand it belongs to the group of highly productive lakes. While the aquatic plant crop appears to be inefficient in its utilization of solar energy, it compares very favorably with some of the more important land crops in this respect. (Juday 1940: 448–9)

Common to both these pioneers, Elton and Tansley, were the use of distinctly agronomic concerns of productivity, yield, and efficiency towards a broader ecological model for measurement of natural as well as artificial ecosystems.73 Such comparisons were distinctly economic. The methods they both followed were identical, only with different foci: how much of the available energy was being 'fixed' at every level, in consideration with the flows. This method will be modified later incorporating the non-living elements in the ecosystem through the concept of 'embodied energy': basic taxonomy however was to remain the same.

Within the ecology fold, Raymond Lindemann 74 offered further refinement to the method of energetics where all the interrelated biological events were reduced in energetic terms. It was termed as the 'most profitable method' within the new scientific paradigm where 'energy became economic' (Worster 1994: 306).

73 Such efficiencies include photosynthetic, exploitation, assimilation, growth, reproductive, production, trophic, just to name a few. There exist clear algebraic relations between them as well. For example, trophic efficiency = exploitation efficiency x assimilation efficiency x production efficiency. For a diagrammatic representation and the formulas, see, Figure 12.9 and table 12.8 respectively in Chapman and Reiss (1995: 141, 147).
1.4.2.2. Metabolism: early beginnings by ecologists

For a unified theory of ecology and economics, it was important to comprehend 'the relation of ecological processes and human practices without simply subsuming the one under the other' (Hayward 1994: 116). Certainly, the object of focus had to be the 'human metabolism with nature'. This included, among others, energetic and material exchanges between human beings and their natural environment, both at an individual and the social level.

Lindemann indeed was the first ecologist to have looked at this 'metabolism' of the whole, by dividing all the resident organisms into a series of more or less discrete 'compartments' or 'trophic levels'. In such an approach based on differentiation of the functional and dynamic components of ecosystems, energy and nutrients in use at one level were found to have never passed on in their entirety to the next higher level, as a portion was lost in the transfer as heat, in conformity with the principles of physics. For a quantification of these losses, 'productivity' was calculated at each level in the food chain along with the 'efficiency' of energy transfers. For the former, the entire biomass at each of the trophic levels was taken into account along with calorific energy required to support the amount of organic matter, a method to be used in energy balance approach later. Accordingly, 'gross production', 'net production', 'gross primary productivity', and 'net primary productivity', and 'ecological efficiency' of

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75 They were producers, primary consumers, secondary consumers, and decomposers.
76 The flow of energy in such a 'box and arrow' framework is generally from plants to herbivores to carnivores (as well as to decomposers all along the food chain). The pyramidal structure of the food chain gives rise to the concept of trophic levels. A trophic level represents a step in the dynamics of energy flow through an ecosystem. The first trophic level is made up of the producers, those within the ecosystem that harvests energy from an outside source like the Sun and stabilizes or 'fixes' it so that it remains in the system. The second level would comprise those who consume the producers, also known as the primary consumers. The next level would contain the secondary consumers (those who consume the primary consumers), and so on. Because of the limited amount of energy available to each level, these trophic pyramids rarely rise above a third or fourth level of structure. In terms of energy flow, trophic level concept has proven valid and useful. Since at each trophic level far more energy is used to power maintenance (metabolism or respiration) than growth (production), total amount of energy flowing through living systems decreases drastically from the lowest to the highest.
77 It was Odum (1969: 262) who had extended the principles of 'ecological succession' and the method of social metabolism to the landscape level.
78 All energy and matter stored or spent at one trophic level.
79 Gross production 'net' of respiration.
80 Total amount of dry matter made by a plant in photosynthesis, in terms of dry weight per unit per unit of time.
81 'Gross Primary Productivity' net of respiration (all definitions are from Chapman and Reiss 1995: 136). Both gross and net primary productivities take account of time and thus are more accurate than the usual productivity calculations employed by economists and agriculturists, where time is absent. For this observation, author is thankful to Prof. Utsa Patnaik.
Introduction

organisms were defined. The last was termed as 'Lindeman's law of trophic efficiency'. In quantitative terms, the efficiency of energy transfer from one trophic level to the next was stated to be about 10%, with the remaining used in metabolism and heat. Further, Lindeman had proposed that organisms high in the food chain were progressively more efficient. However, Chapman and Reiss (1995: 146) reported that recent data supported neither Lindeman's proposition of progressively increasing efficiencies within a food chain nor the 10% criterion for energy transfer. Behaviour and physiology of the organisms were found to be more important determinants in the variation in trophic efficiencies, rather than the relative positions of the organisms in the food web.

Worster (1994: 310) had noted the general findings of the scientists using the same method: productivity and efficiency across ecosystems for the land-based ones were found to be higher than the aquatic ones, though with important exceptions. However, across all types of ecosystems, the primary efficiency of solar energy capture was near 1 per cent. Technically, this 'efficiency of photosynthesis', first conceptualized and calculated by Transeau in 1926 in the corn field, equalled total energy fixed in photosynthesis/total energy falling on the field. The significance of this estimation of photosynthetic yield in agriculture was enormous, as it is today: perhaps more so now, given the depletion of energy sources of 'bottled sunshine', 'a store of solar energy from past lifeforms' (Boulding 1973: 122).

[... In short, ecology at last emerged as a full-blown science of natural economics, fulfilling a vague promise more than two centuries old. [...] Without economics, ecologists might have disappeared as an independent class of researchers; as it is, ecology claimed a clear, safe, and highly prominent place squarely between the two most influential disciplines of our times [Economics and Physics]. (Worster 1994: 311–2)


See, Table 12.1 & 12.3 in Chapman and Reiss (1995: 137, 140) for details.
1.4.2.3. Early beginning of energy and economics—transdisciplinary agricultural energetics

Martinez-alier (1987: 20) considered the following markers for the 'non-existent' discipline of ecological agricultural economics: the study of the cycles of materials during the 1840s and 1850s, beginning of agricultural energetics in around 1880, studies on the flow of energy in the 1970s and interest in the genetic variability in agro-ecosystems in the 1980s.

Corning (2002) argued that the roots of the 'long-standing but uneasy relationship between energetics and the discipline of economics', could be traced back to Jean Baptiste de Lamarck, Herbert Spencer, Ludwig Boltzmann and many others in the nineteenth century, who drew attention to the central role of energy capture and utilization in living systems. In the twentieth century, demographer cum physicist Alfred Lotka was the first to view the role of energy and evolution within the context of natural selection, apart from using an energetic perspective to illuminate the 'biophysical foundations of economics'. On the other hand, in the 1920s and 1930s, physical chemist and Nobel Laureate Frederick Soddy became the most vigorous proponent of an energy theory of economic value. Interestingly, most of the work done by non-economists in the past, like Rappaport, Odum, Pimentel, Leach, Chapman, and Cottrell, were in the sphere of agricultural energetics. Despite this long history of interaction between human ecological energetics and economics however, evaluation of the use of energy in the economy has only been a recent phenomenon (Martinez-alier 1987).

A more or less universal conclusion reached by these studies was that 'in principle, energy analysis and conventional economics seem to give contradictory judgments of the same process' (Martinez-alier 1987: 3). Energy analysis had found the traditional agriculture to be more efficient than modern agriculture, and also that the productivity of agriculture has not increased, but decreased over time. Notwithstanding the several limitations of energy analysis including its inability to undertake a cost-benefit analysis incorporating the present discounted value, something that may seem more profitable in monetary terms to a farmer, was not to be in terms of 'ecological agricultural energetics'.

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85 One reason for higher monetary productivity (and lower energy efficiency) of the modern agriculture is subsidised energy inputs. Incorporation of negative externalities further reduces the productivity of modern agriculture.
It is a fact, for instance, that different agricultural products have use values which are not always related to their energy content, and even less to their energy cost, but rather to their protein or vitamin content, or simply to the pleasure to be gained by eating or drinking them. Nevertheless, such studies of the flow of energy in agriculture show that it is not appropriate to analyse economic growth in terms of an increased productivity of agriculture [...]. (Martinez-alier 1987: 3)

Frederick Soddy during the 1921 lectures delivered to students at London School of Economics and Birbeck College spoke about 'vital use' and 'laboral use' of energy in the context of the role of agriculture in the economy. This crucial difference was in line with the classical framework, and pointed towards energy sources as a flow and stock.

Herman Daly and John Cobb joined Soddy in criticising economists for mistaking chrematistics as economics. The former meant 'the manipulation of property and wealth so as to maximize short-term monetary exchange value to the owner' while the latter word with roots to oikonomia, was connected with good life (Hayward 1994: 91).

First, it [oikomania] takes the long-run rather than the short-run view. Second, it considers costs and benefits to the whole community, not just to the parties to the transaction. Third, it focuses on concrete use value and the limited accumulation thereof, rather than on abstract exchange value and its impetus toward unlimited accumulation. (Daly and Cobb 1990: 139)

The contribution of Ukrainian populist and socialist physician Serhii Podolinsky's in ecological energetics was twofold (see, Podolinsky 1881/2004). The first was his emphasis that the viability of a society requires that 'the energy return to human energy expenditure covers the energy cost of human labour' (Martinez-alier 1987: 11). The second was his characterisation of 'productive work' by human and animal labour, and plants, for their capabilities in offering 'protection against the dissipation of energy into space', which could only be achieved

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86 Former meant photosynthesis in plants and carbon oxidation in the nutrition of animals while the latter referred to the use of instruments by human beings, moved by the wind, waterfall, steam or internal combustion engine. While viral use of energy could not vary much from person to person, laboral use varied a lot from across individual, country, historical periods. This observation of Soddy is similar to that of Serhii Podolinsky, Eduard Sacher and Patrick Geddes (Martinez-alier 1987: 136).

87 Also defined as 'the branch of political economy relating to the manipulation of property and wealth so as to maximize short-term monetary exchange value to the owner' [Daly and Cobb (1989: 138) as cited in Gowdy and Mesner (1998: 152)]. Ecological economists allege that '[t]he subject matter of [the mainstream] neoclassical economics has been reduced to chrematistics, as value has become synonymous with exchange value and the maximization principle equated with rationality' (Gowdy and Mesner 1998: 152).

88 Herman Daly and John B Cobb, 1990, For the Common Good: Redirecting the Economy towards Community, the Environment, and a Sustainable Future, London: Green Print, quoted in Hayward (1994: 92).
through agriculture (Martinez-alier 1987: 50; see, 2.3.1 below). Engels had agreed on the application of this principle in most primitive branches of production like hunting, fishing, cattle-raising, agriculture (Engels 1986a). However, he remained unconvinced over the ‘fixity’ of energy and expressed reservation on the energy value of fertilizers and other auxiliary means like use of steam engine in threshing. Arguably, the latter were difficult to compute, given the then state of knowledge.

Podolinksy's other contribution was related to his analysis of capacity of the human organism to perform work. This had led to his incorrect assertion that that man was a more efficient transformer of energy than a steam engine with a much lower conversion rate. The consequent argument that humanity was a 'perfect machine' a la Sadi Carnot, had drawn Engels' rather heavy criticism (see, 2.3.1 below, for a detailed discussion).

Podolinsky had been credited by Martinez-alier (1987: 51) as the pioneer of the idea ‘that one could determine the necessary minimum conditions of human survival on earth through an analysis of energy flows and energy coefficients’. This idea, arguably, is no different from the extension of Marxian concept of ‘labour-power’ as pointed out by Dobb (1973: 151) noted above, and followed in this thesis.

Among the ‘physical indices of (un)sustainability’, the ‘energy return on (energy) input’ or EROI, that had been pioneered by the noted ecologist H T Odum, followed Podolinsky’s idea of looking at the basic economics of human society on the basis of energy flow. Eduard Sacher also had followed Podolinsky in studying the flow of energy in agriculture. His attempt to correlate stages of cultural progress with energy availability per caput, was even before Patrick

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89 The quantum of such fixing would of course be dependent on the degree of development of the means of production, Podolinsky had contended (Martinez-alier 1987: 47).
90 Others are (1) Human Appropriation of Net Primary Production (HANPP), (2) Ecological Footprint, and (3) Material Input per Unit Service (and its variation Domestic Extraction/Production of Natural Resources).
91 Physiologically speaking, he took the amount of physical work that a person could do in a day, as 1,000 Cal, for which at least 3,000 Cal was required in the form of food. However, the economic work performed was estimated to be only about 450 Cal/day/worker in the macro sense considering share of economically active population, period of economic work, etc. For him, the economic task before the labour force was 'winning' the maximum amount of energy from nature (Martinez-alier 1987: 65). To be discussed in more detail below.
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Geddes,\textsuperscript{92} Henry Adams and Wilhelm Ostwald (Martinez-alier 1987: 65–8).\textsuperscript{93} His interest in finding out the ways, in which the surplus energy was appropriated by some of the groups in society to the exclusion of many others beyond the needs of subsistence, had a distinct Physiocratic, if not Marxist aura. Notwithstanding his 'energetic dogma' a la Georgescu-roegen in not considering any resource other than energy, Sacher had admitted the limitation of energy theory of exchange-value. Further the absence of 'mental work' in energy values and thus of skills, training, and other such possibilities of improvement in the productivity of human labour was pointed out by him, and remained an important limitation of the human labour energetics.

Josef Popper-Lynkeus (1838–1921), a member of the 'Austrian school' of ecological economics, had proposed a study of the economy in terms of the flow of materials and energy and perhaps was the first one to recommend moderation in the use of exhaustible resources.\textsuperscript{94} Leopold Pfaundler, the other member of the Austrian School, followed Popper-Lynkeus in designating the term 'energy crisis', to describe a situation with humans not being able to obtain 2,000 or 2,500 Cal per day, a requirement for their minimum sustenance, unlike its present usage bereft of any human dimension (Martinez-alier 1987: 10). On the basis of the then state of knowledge in physiology and nutrition, Pfaundler had made a claim in 1902, that the effort of a worker required 'on average, 118 grams of protein (sic), 56 grams of fat, and 500 grams of carbohydrate' to produce 3,055 Cal, with the calorie requirement varying according to race, intensity of work, sex and climate (Martinez-alier 1987: 108–9). German energy physiologist Ludimer Hermann

\textsuperscript{92} Geddes' contribution in energetics lay in his proposal to construct an input-output table like \textit{Tableau Economique}, that included the losses at each stage of transformation in the form of dissipation and disintegration (Martinez-alier 1987: 94–5).

\textsuperscript{93} Friedrich Wilhelm Ostwald, a German physical chemist is considered the founder of the 'school of energetics', and credited with being the originator of the term 'human energetics', a near-synonym and precursor to 'human thermodynamics'.

\textsuperscript{94} In particular, Popper-Lynkeus recommended how the use exhaustible resources available to Germany just before the First World War could be gradually reduced so as to ensure the permanent viability of the economic system. His 1912 publication, \textit{Die allgemeine Nährpflicht als Lösung der sozialen Frage} (On the general duty of nutrition as a solution to the social question, statistically researched, with a demonstration of the lack of theoretical and practical validity of economic theory) had been described as one fundamental text of ecological economics. Here, one finds the foundational thoughts of the later 'basic needs approach' in Development Economics. Requirements of human work were calculated so as to guarantee the whole population a subsistence minimum, clothing, housing and health services, to be provided by a 'conscription for food production', rather than the military one. The basic needs sector of the economy was to provide the subsistence minimum, free of charge to everybody, and the remaining sectors were to run on the principles of market economy, in Popper-Lynkeus's framework (Martinez-alier 1987).
had followed this framework, which had influenced Marx in his analysis of labour power.

1.4.2.3.1. Energy, Entropy and Economics in Agriculture
A Romanian mathematician with a doctoral thesis on Statistics (1930), and an early interest in agrarian economics, Nicholas Georgescu-roegen had published The Entropy Law and Economic Process in 1971. He was one of the founders of the emerging discipline of Ecological Economics, and a staunch critic of the orthodox economic discipline over its mechanistic outlook. With the thermodynamic 'revolution' in Physics, Georgescu-roegen argued, it was important to move out of the mechanistic dogma, as 'the significant fact for the economist is that the new science of thermodynamics began as a physics of economic value and, basically, can still be regarded as such. The Entropy Law itself emerges as the most economic in nature of all natural laws' (1971: 3; emphasis as in original).

The entropy law, or the second law of thermodynamics, was argued to be all pervasive: even if one living being may evade the entropic degradation of its own structure, for the whole system it was inevitable. While acknowledging Alfred Marshall and physical biologist Alfred J Lotka, Georgescu went on defining economic development in terms of 'development proper' and 'pure growth' in entropy terms, before declaring that the 'economic history of mankind leaves no doubt about this entropic struggle of man' (1971: 294). In particular, relative

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95 In particular, he had blamed Jevons and Walras, the founders of modern economics for creating an 'economic science after the exact pattern of mechanics, [...] [which] can neither account for the existence of enduring qualitative changes in nature nor accept this existence as an independent fact [...] [as it] knows only locomotion, and locomotion is both reversible and qualityless' (1971: 1). The corresponding economic process 'is an isolated, self-contained and ahistorical process—a circular flow between production and consumption with no outlets and no inlets, as the elementary textbook depicts it' (1971: 2).

96 Käberger and Månsson (2001: 172), both physicists, commented:

One of the most important contributions of Georgescu-Roegen was his attempt to change the systems view of economics from this conventional (monetary) circular to the (partly physical) throughput one [...], thereby bringing economists and economics back towards reality. In particular, whereas the conventional models of the economic system were without connection to the physical world and thereby unconstrained by the laws applying there, the models with the economy as a throughput system have considerably less freedom of action, implementing some of the physical and other constraints that apply in society.

97 In general, the total entropy of any system will not decrease other than by increasing the entropy of some other system. Hence, in a system isolated from its environment, the entropy of that system will tend not to decrease. It follows that the entropy of a system that is not isolated may decrease. In mechanics, the second law in conjunction with the fundamental thermodynamic relation places limits on a system's ability to do useful work.
scarcities of the two sources of low entropy, the solar radiation and the earth's own deposits was argued to be having a very strong connection with the balance and general direction of economic development. While solar energy was more associated with husbandry, minerals were with the industry (1971: 297). At the same time, partnership between man and the nature in the agriculture was distinctly 'more stringent and more subtle' than the other, for three reasons.

First, as nature dictates the schedule of agricultural activity, doubling the amount of labour used with same 'material funds' may not double the product flow. Second was the impossibility of stocking solar energy at a rate desirable by human beings due to the limits determined by the gradient of the sunrays on the earth's surface and the global position in the solar system.98 Third, the subtle ways in which nature assists the farmer imply that the 'process' in agriculture must be followed rigidly as per the 'blueprint', unlike industry where certain margins are permitted.

Georgescu-roegen joined many of his predecessors in bestowing centrality to the agriculture sector in the development process,99 and was particularly critical of the practices that eliminated draft animals as a source of power as well as manure, and replaced them with the oil-fed 'mechanical buffalo' and the chemical fertilisers. This had resulted in a replacement of power source from sun's radiation to 'an additional tapping of the stock of mineral resources in the earth's crust' (1971: 303). Incidentally, the highest estimate of terrestrial energy resources was argued to be rather meagre: less than the amount of solar energy received during four days (Ayres 1950: 16).100 Thus, technological progress that had resulted in a shift from this abundant source of low entropy to a relatively scarce one, was nothing but 'the degradation of man's dowry of low entropy as a result of his own ambitious activity that determines both what man can and cannot do' (1971: 305).

98 'Agriculture teaches, nay, obliges man to be patient—a reason why peasants have a philosophical attitude in life pronouncedly different from that of industrial communities' (1971: 297)
1.4.2.4. Energetics in Human Society—Nature Exchanges

The unification or convergence of ecology and economics continued through multiple routes: the one rooted in thermodynamics took place through the concept of social metabolism, as noted earlier. The metabolism is regulated on the one side by physical processes based on natural laws and on the other, institutional norms governing the division of labour and distribution of wealth, etc. In Marx's writings, Stoffwechsel or metabolism appeared ever since the Grundrisse. In Capital, it was used for conceptualising the breakdown in humanity's relationship with nature: 'Capitalist production [...] disturbs the metabolic interaction between man and nature, i.e., prevents the return to the soil of its constituent elements consumed by man in the form of food and clothing; hence it hinders the operation of the eternal natural condition for the lasting fertility of the soil' (1954a: 474). This separation of human society from nature is what Foster (2001) had termed as 'metabolic rift', a concept intrinsically connected with the flow of nutrients in the soil. This separation had been argued to serve as the basis for 'capitalism's fundamental form of valuation' (Burkett 2003: 160).

Foster (2001: 240) found Nikolai Bukharin as one of the early followers of Marx and Engels, to take forward Marx's concept of metabolic interaction between human beings and nature. 'Chapter 5: The Equilibrium between Society and Nature' of Bukharin (1921/1969), had elaborated the type, nature, extent and dependence of the interrelationship between human society and the 'external nature' or its environment, in terms of 'energy income' and 'energy expenditure'. This interrelationship, arguably, is identical to the method of energy balance analysis.

Human society, like any system, exists in a non-empty space, i.e. within an 'environment', that ultimately determines all its conditions. Human society—

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101 Social metabolism brings together just not two but many other disciplines in dialogues with each other. 'There is a common ground between social history, economic history and environmental history, between ecological economics and political ecology, between sustainability science and environmental sociology' (Martinez-alier 2009: 62). See, Fischer-Kowalski (2002) for a transdisciplinary history of the concept of metabolism, covering biology, agronomy, ecology, social theory, cultural & ecological anthropology, social geography, and geology. Fischer-Kowalski and Haberl (2007) addressed transitions in the use of energy and materials, patterns of human time-use, and economic changes by combining elements of human ecology, environmental history, and ecological economics, to explain the past and project the future possibilities.
environment relationship determine the alterations in the system as well as the fundamental direction of its growth (progress, rest, or destruction). The process through which such deterministic interaction takes place is through ‘abstractions’ and eventual appropriation of energy from nature by the human society: ‘without these loans it could not exist’ (Bukharin 1921/1969: 107). Further, this ‘abstraction of energy from nature, is a material process [...] [and] [t]his material process of "metabolism" between society and nature is the fundamental relation between environment and system, between "external conditions" and human society’ (Bukharin 1921/1969: 108). Such contact takes place through the process of human labour: ‘[b]y work, energy is transferred from nature to society; and it is on this energy that society lives and develops (if it develops at all)’ (Bukharin 1921/1969: 89–90). Clearly, the higher is the amount of such appropriation, the greater will be the societal growth. Marx had explained this process as follows:

 [...] Labour is, in the first place, a process in which both man and Nature participate, and in which man of his own accord starts, regulates, and controls the material re-actions between himself and Nature. He opposes himself to Nature as one of her own forces, setting in motion arms and legs, head and hands, the natural forces of his body, in order to appropriate Nature's productions in a form adapted to his own wants. [...] At the end of every labour-process, we get a result that already existed in the imagination of the labourer at its commencement. [...] 

The elementary factors of the labour-process are 1, the personal activity of man, i.e., work itself, 2, the subject of that work, and 3, its instruments. 

The soil (and this, economically speaking, includes water) in the virgin state in which it supplies man with necessaries or the means of subsistence ready to hand, exists independently of him, and is the universal subject of human labour. All those things which labour merely separates from immediate connexion with their environment, are subjects of labour spontaneously provided by Nature. (Marx 1954a: 173–4)

In Bukharin’s framework, production involved ‘expenditure of human energy’ to extract energy from nature. Such extracted energy is appropriated by the society through the process of consumption, which became the basis for further expenditure, and this ‘wheel of reproduction being thus constantly in motion’ (Bukharin 1921/1969: 110), recalling once again the idea of the Physiocrats. In this interaction between society and nature, when society applies its human labour energy, it also receives a certain quantity of energy from nature. It is this ‘balance between expenditure and receipts’ that is ‘the decisive element for the

102 Just as the savage must wrestle with Nature to satisfy his wants, to maintain and reproduce life, so must civilised man, and he must do so in all social formations and under all possible modes of production. [...] Freedom in this field can only consist in [...] rationally regulating their interchange with Nature, bringing it under their common control, instead of being ruled by it as by the blind forces of Nature; and achieving this with the least expenditure of energy and under conditions most favourable to, and worthy of, their human nature. (Marx 1954c: 820; emphasis added)
growth of society' (Bukharin 1921/1969: 112). The three cases with varying working time to cover the society's most rudimentary needs that Bukharin (1921/1969: 112) had discussed, made the importance of spending lesser and lesser time to produce the identical quantity of objects amply clear.

Yield or 'productivity of social labour' thus determined the growth (or retrogression) of the society. This was stated to be equal to the quantity of product per unit of working time, say, a year and represented the relation between the quantity of product obtained and the quantity of labour expended (Bukharin 1921/1969: 113). Alternatively, productivity of social labour represents the 'relation between nature and society [...] expressed in the relation between the quantity of useful energy turned out and the expenditure of social labor' (Bukharin 1921/1969: 114–15). Materially speaking in quantitative terms, productivity of labour is concerned with three things—the products obtained, the instruments of production (the 'crystallized labour') and the productive forces (the 'living labor') (Bukharin 1921/1969: 115).

Living labour equalled the 'direct expenditure of working energy' (Bukharin 1921/1969: 115) which arguably could be made to correspond to the food calorie intake. On the other hand, for the instruments and other materials, energy analysis may be employed, to arrive at a balance similar to the one that Bukharin had pointed to ninety years ago.
1.5. Energy in Economic System

Energy is present in all processes and there are no substitutes for it. It is a unifying concept for all materials, in terms of their thermodynamic potential. Energy Analysis traces the changes in thermodynamic potential of materials in quantitative terms, while they pass through successive stages of process(es). For thermodynamicists, energy content is an inherent property of the system, including all living systems, as the latter are dependent on an adequate supply of energy and materials to support life-sustaining processes.

Thermodynamic laws indeed explain the physical constraints on ecological processes. In ecological thermodynamics, the fundamental principle remains in terms of materials cycling in ecosystems, with energy flowing through them. All energy that powers life (except nuclear and geothermal energy) began with the sun and takes place in direct (as in the case of photosynthesis) or transformed form (as in the case of food intake). At the end, the energy flowing through living things is ultimately lost as heat (from movement, metabolism, and decomposition) and radiation.\(^{103}\) Whenever heat is converted into work, increase in entropy or order that takes place, is known as negentropy.

Importance of energy in the economic system arose due to its appearance as a commodity, an input or an intermediate good in the economic processes. Indeed, the physical properties of energy became significant in the economic relations. To quote Kenneth Boulding (1973: 121), ['t]he critical question is: why is energy necessary to sustain or to increase affluence—affluence in this case considered as an indicator which increases when an individual moves from a less preferred to a more preferred condition or state?' While, affluence is measured here by both stock (wealth) and flow (income) concepts, its increase through more use of energy inputs had accompanied the twin problems of pollution and exhaustion.

There is ample historical evidence on how the absence of human prudence on the face of apparent abundance of energy and other natural resources had led to the

\(^{103}\) As it is well known, first law of thermodynamics state that heat is neither lost nor gained, and the second law defines the manner in which negentropy is consumed when a non-spontaneous process works.
decline of civilizations. However, there is a vast difference between the present exhaustible fossil-fuel based mode of resource use and the earlier ones built on essentially renewable and inexhaustible energy resources. For the 'bottled sunshine', not only its availability but also the knowledge about its efficient uses, assumes greater importance now. However, its recognition among the economists had been rather late, in contrast to the other disciplines as stated earlier. For instance, consider the sociologist Roger Cottrell who had written in 1955 about the possibility of energy putting a 'limit on what man can do'.

1.5.1. Energetic Response to the Energy Crisis

The field of environmental and resource economics that had started in US and Europe grew rapidly since the early 1970s. In 1970s and most of 1980s research was highly concentrated on two issues of valuation of the benefits of environmental amenities and the costs of pollution control, and the design of and choice among policy instruments, essentially within the framework of and following the method of welfare economics. The role of physical–biological perspectives inside environmental economics were humble to say the most (Røpke 2004:302).

Ideas floated since 1970s by pioneers of ecological economics, like Georgescu-Roegen and Herman Daly, resulted in the emergence of a new field of energy studies, primarily as a response to the energy crisis. However, the relationship between the energy and the economy from the biophysical perspective took off rather rapidly since the end of 1970s, as noted earlier. Researchers were from many disciplines including physics, engineering, systems ecology and also economics. A parallel development was of industrial ecology: of note is the chapter on 'Application of Physical Principles to Economics' in Ayres (1978) that had brought energy efficiency and negentropy into focus. The common point of attention was the depleting fossil fuels.

[...] You can't understand the last two hundred years of human history without understanding energy. We could have accumulated vast amounts of capital, but it wouldn't have done what it has done for us, had it not exploited

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104 For the resource perspective, see, Chew (1999) that analysed 'political, economic and ecological relations circumscribing the dynamics of the reproduction and decline of two socioeconomic organizations (Mesopotamia and Harappa) during the Bronze Age'.

105 He was stated to be 'the first to demonstrate that economies with access to energy sources with a large energy surplus have greater potential for economic expansion and/or diversification than those with access to lower quality fuels' [Cutler Cleveland in forward to Cottrell (1955/2009)].
fossil fuels. Energy is what you need to do work, and doing work is what economics is about. (Michael Common, quoted in Røpke 2004:303)

In the face of rapidly exhausting fossil fuel resource, it became important to locate possible enhancements in efficiency in the use of this scarce factor and development of its renewable alternatives. By the early 1990s, fossil fuel had marked its presence in the operationalisation of sustainable development principles, floated by pioneering ecological economists like Daly and Costanza (1992: 44). Among others, Kenneth Boulding had theorised the role of energy as a 'limiting factor':

The most important limiting factor is the one that is most limiting, that is the one that actually limits the process. Sometimes this may be energy, sometimes materials, sometimes space, sometimes time. [...] Which of these four limiting factors in fact limits the process is an empirical matter, and varies from process to process. (1992: 239-41; emphasis as in original)

Boulding (1992: 241) argued further that empirical discovery of these limiting functions poses a severe problem, with their heterogeneity adding onto it. Heterogeneity of the 'contributive factors' indeed had become so much 'as to be almost as worthless as earth, air, fire, and water as factors in the theory of production' (Boulding 1992: 243). Earlier, Duckham and Masefield (1970: 21) had already considered the possibility of energy and moisture regimes as one of the limiting factors that may reduce the number of actual systems than the ecologically possible ones. But technological optimists like Huettner (1982: 1142) were ready to challenge the 'unacceptable but also arbitrary' assumption of considering energy as the ultimate limiting factor with the argument that technological change could very well be 'the ultimate limiting factor or argue that other resources could be depleted before energy exhaustion is reached'.

[...] There are, in fact, some good reasons for considering available energy the ultimate limiting factor. It is the only input that is both necessary for all productive activities and impossible to create internally or recycle. It must be supplied from outside the system and can only be dissipated internally. The same cannot be said for the other "intermediate" factors of production, land, labor, capital, and technology. Technological change is certainly an important characteristic of our economic growth, but it is no more independent of direct and indirect energy costs than any other component of the economy. [...] We can expect technological change to help us adapt to new energy sources, but it cannot create available energy. (Costanza 1982: 1143)

106 The conventional economic or contributive factors of land, labour and capital are all mixtures of limiting factors in this framework—space, soil, materials and solar energy input in the case of land; time, human energy throughput and nutritive materials throughput in the case of labour; all the limiting factors in the case of capital.
However, notwithstanding the complexity involved in identifying the limiting factor at various spatio-temporal coordinates,\textsuperscript{107} two facts stood out vis-a-vis energy, Boulding (1992: 244) concluded, even while acknowledging the difficulty in proving it in empirical terms. First, over the course of the biological evolution, energy had not been the limiting factor, but it was the space or the materials, and different discoveries like the fire, agriculture, fossil fuel, had helped the human beings to expand their ‘niche’. Second, like in the past, only a very small fraction of the flow of solar energy was being utilized by the biosphere, and given the imminent exhaustion of fossil fuel, it has become necessary to find its substitutes along with more efficient utilization of solar energy and regulated use of the fossil fuel itself. Finally, available evidence more than conclusively proved that for the production processes using more of fossil fuel energy sources, energy will be the first limiting factor.

Among others, Cleveland et al. (1984: 892) declared that ‘a physical analysis of economic production provides realistic assessments of the problems we face and some of the needed characteristics of any plausible solution’. The advanced argument was two-fold, focussing on the physical interdependence of capital, labour and natural resources: first, for a differential treatment of fuel and mineral resources among the factors of production owing to their non-substitutability with reproducible capital and second, importance of ‘free’ or low entropy energy to maintain and upgrade all organised structures including capital and labourers.

\textbf{1.5.2. Energy in Agriculture}

There are three primary reasons for energy use in agriculture attaining importance over the last 40 years or so. First, with respect to the negative externalities including greenhouse gas emissions; second, the falling efficiency of the ‘modern’ farming systems, that is, relation between energy input and output, in an absolute as well in relative terms vis-a-vis traditional ones; and third, share of the exhaustible energy sources in total input.

As noted in 1.4.2.3 above, from the very beginning, energy and economics linkage had been applied mostly in agricultural systems. Post energy crisis,\textsuperscript{107}

\textsuperscript{107} Over the historical modes of resource use, energy has played a very distinct role in the evolution of society, in terms of the sources which it could access and the ways they could be utilized. See, Chapter 1: Habitats in Human History in Gadgil and Guha (1992) for details.
methodological issues became more important resulting in formalisation of a variety of methods, that included energy accounting, energy balancing, energy budgeting and energy costing. The subsequent vast literature that began with the classic paper by Piementel et al. (1973) was quickly followed by many at the international arena (Stanhil1 1974, Lockeretz 1977, Mitchell 1979, Pimentel 1980a, Stanhill 1984, Fluck 1992, just to mention a few). These studies were conducted at different scales (individual plots, district, State or the country), of various inputs (individually or groups or in combination), of a variety of practices, or of individual operations. There still exists, however, considerable diversity within each of these methodologies. Conflicting assumptions across methods, over aggregation, quantification, as well as handling of inputs, especially labour (Norum 1983) as well as unsettled questions over its nature, scope, boundary of analysis, research questions, accounting nomenclature, treatment of inputs, interpretation of results, and limitations (Jones 1989: 340) have remained. Each of the difficulties, however, can be addressed with a careful handling, while retaining the basic nomenclature.

For Common (1995: 209–212), energy analysis may provide the useful information, to be used with standard economic data, for public policy decisions. In particular, it had been advanced as ‘one useful way of thinking about sustainability issues’ (Common 1995: 198). One of the three reasons advanced in favour of energy analysis included the advantage of this method in 'making plain what is implicit but not readily apparent in the economic data, and can suggest new perspectives', especially in the food production systems. In fact, it was particularly favoured in relation to the understanding of current and historic conditions (Common 1995: 211), for its timelessness dimension.

One may note that, efforts in India in this regard were not negligible, yet scanty. Bhatia (1977) was the first attempt that captured consumption of energy in Indian agriculture from various sources and changes in the pattern over 1951–71. More importantly, it compared bullocks as a source of power vis-a-vis tractors and irrigation pumps. Attempt by Moulik et al. (1990) to make a forecast of energy demand for agriculture in India included evolving a methodology of estimation based on disaggregated energy-input data (based on direct and indirect sources

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108 Exception is the time-energy studies, that predate energy-agriculture writings by many years. Consider for example, Wirths (1956) or Hermann (1875).
for crop, agro-climatic zone, and farmer category). Accordingly, State-wise crop-wise energy per hectare (MJ/ha) was projected. Indian Council of Agricultural Research (ICAR) had conducted an All India Co-ordinated Research Project (AICRP) on 'Energy Requirements in Agriculture Sector' (1971–2002). Apart from various interim research digests (Mittal, Mittal and Dhawan 1985; Singh, Bakshi and Singh 1988), journal articles and books (Singh and Mittal 1992), the synthesis report was published as De (2005). Ramakrishnan (1992) had a chapter on energy budget under jhum cultivation practiced in North-eastern India.

Literature in Indian social science journals are represented by Chopra (1992) in Indian Economic Review, Prakash and Mohammad (1997) in Geographical Review of India, an issue of Indian Journal of Agricultural Economics (1998) with 'Economics of Energy in Agriculture' as a subject, and Singh and Saran (2004) in Indian Journal of Economics. Among social scientists, Parikh (1985) and Parikh and Kromer (1985) in Energy remained the only notable contribution on agricultural energetics. Interestingly, none of the authors in the section on 'Impact of Agricultural Development on Ecology and Environment' of Indian Journal of Agricultural Economics (1987) mentioned energy! Similarly, neither the author of 'Agriculture and Environment' in Handbook of Agriculture in India (2007: Oxford) nor the editor of this volume found energy to be important enough to be discussed. Neither did the editors of the 27 volume State of the Indian Farmer: A Millennium Study (2004: Academic Foundation). On the other hand, there had been a steady flow of contributions from the community of Indian natural scientists in internationally renowned journals like Agro-ecosystems, or Agriculture, Ecosystems & Environment, Agricultural Engineering International, Energy Policy and the like. One of the objectives of this work is to fill such a gap in the agricultural energetics, from the social sciences as such.
1.5.3. Impact of Land Constraint on Energy

Conforti and Giampietro (1997) had examined the comparative importance of constraints in land and labour endowment for energy balance in agriculture, assessed at the level of national crop production systems. Relations between output/input energy ratio of agriculture,\textsuperscript{109} average labour productivity,\textsuperscript{110} and land productivity\textsuperscript{111} were explored over a 75-country sample taken from FAOSTAT-PC data bank using a cluster analysis procedure (into five groups), through a cross-section equation that explained output/input ratio in terms of intensity of land and labour-food-energy throughputs, for averages of two years (1990–1991).\textsuperscript{112}

Expectedly, India was found along with developing countries of Sub-Saharan Africa, South Asia and Latin America, characterised with highest output/input ratio, high share of labour force in agriculture (>50%), and homogeneously small endowments of arable land/farmer. Output and input per farmer and per hectare, expectedly again, was found to be lowest among all groups, notwithstanding wide differences over per hectare energy input and outputs among the countries in the cluster (1997: 240). Though the conclusion remained tentative and limited, which was acknowledged, due to the use of ‘aggregated data, aggregated conversion factors and simple statistical tools’, the results did suggest that a land constraint, with respect to the total population size, rather than labour constraints, tended to be associated with comparatively higher energy requirements in agricultural production.

In other words, increase in ‘emancipation’ from land shortage of agricultural production could be seen from the increased payment in terms of biophysical cost, namely fossil fuel energy. The latter was found to be connected with the negative environmental impact, be it from soil erosion or depleted water table,

\textsuperscript{109} Output as the food energy in crops and input as the commercial energy embodied in technical inputs.

\textsuperscript{110} Food energy produced per hour of labour allocated to agriculture.

\textsuperscript{111} Food energy output per hectare of cropped land.

\textsuperscript{112} Variable included, output/input, arable land/farmer (in ha), output/farmer (in GJ), input/farmer (in GJ), output/hectare of arable land (in GJ), input/hectare of land (GJ), workforce in agriculture (in GJ), while crops were cereals, starchy roots, pulses, oil crops, sugar crops, stimulants (coffee, cocoa and spices), fruits and vegetables with completely excluding animal products for the complication of apportioning agricultural products between food and feed.
resulting increases in the biophysical cost. Clearly, either type of biophysical costs is not explicitly taken into consideration in the usual economic analyses.

Exothermic converters of energy\textsuperscript{113} had enabled the pre-industrial societies to eliminate the power bottlenecks. Further, increased reliance on stock exploitation, in contrast to that of a fund, following the concepts used by Georgescu-roegen,\textsuperscript{114} had eliminated the land bottleneck, together with the use of renewable energy inputs. As a result, massive switches from animal and human labour power to machine power, added to by increase in use of fossil fuel had brought increase in economic productivity at the end of eighteenth century, most notably witnessed during the second agricultural revolution (Conforti and Giampietro 1997: 231).

However, such ‘technical change’ which induced dependence on fossil fuel use, also implied the absence of any real ‘emancipation’ of production from natural resource base, which is particularly true of agriculture. Indeed the threat to food insecurity that rise in price of fossil fuel had extended, underscored the connection between increase in land productivity and intensification of fossil fuel use. The environmental consequences of such agricultural activities that are heavily dependent on technical inputs, jeopardised the viability of yield increases

\textsuperscript{113} Devices or machines that convert energy inputs into useful energy outside human bodies.

\textsuperscript{114} A fund, like the Ricardian land with ‘original and indestructible powers’, labour power or capital equipment enter a production process and (ideally) comes out without any ‘impairment of its economic efficiency’ and thus is expected to be perfectly maintained during the process. A stock is not a stock, with the timescale of accumulation or decumulation being vastly different. A stock of 1 kg of rice is a stock that can distributed between 5 persons in one single instant or to a single person over 5 days. A fund, in contrast, like a certain quantity of labour power, cannot necessarily be used at a particular point of time. While all stocks follow accumulation or followed by decumulation in a flow, not all flows like electricity involve a rise or fall in a stock (Marzetti 2009). Alternatively, flows can be seen as the connections between the economy which is an open subsystem of the larger ecosystem that contains and sustains the economy: the flow of material throughput that include source-side flow of raw material and sink-side flow of wastes, while originates from the stock, ecosystem services originate out of the fund. A stock can function as a fund, say, a forest, resulting in a different kind of flows: material throughput like kendu leaves, and also various climate-stabilising services (Malghan 2010). However, the ability of the a forest, to provide valuable services in its role as a fund depends on a particular configuration of the stocks that make up the forest. Even the natural regeneration rate of the constituent stock is dependent on a particular configuration of the underlying fund-configuration. For example, a captive plantation with the same standing-stock of timber as a forest but with diverse species regenerating at a different rate provides different levels of micro-climate stabilisation service. The fund service, however, is not a physical flow like the throughput derived from the stock-function of the ecosystem. These essentially are very small ‘rates of flow’, and were termed as service flux to distinguish ecosystem services (as a fund-function of the ecosystem), from resource flows (as a stock-function) (Malghan 2010). Fund services are different from flows, as the former is expressed in terms of substance x time, while the former is defined in terms of a substance/time.
in the long run. The central point of concern has been that the consumption of fossil fuel energy has risen faster than its production (Martinez-alier 1987), clearly pointing to the unsustainability of such practices in the long run (Conforti and Giampietro 1997: 232). In the language of Mayumi (2001b), the land problem reflects the bias of 'efficiency of type 2' (or ratio of output per unit of time, without any consideration to the amount of inputs to obtain the output) over the 'efficiency of type 1' (or ratio of output to input, without consideration of the time required to obtain the output). Alternatively, it is speed of entropy that poses important problems for the course of development.

1.6. Approaching the Sustainability of Agriculture

[...] Storage of energy through work really only takes place in agriculture; in cattle raising the energy accumulated in the plants is simply transferred as a whole to the animals, and one can only speak of storage of energy in the sense that without cattle-raising, nutritious plants wither uselessly, whereas with it they are utilised. In all branches of industry, on the other hand, energy is only expended. The most that has to be taken into consideration is the fact that vegetable products, wood, straw, flax, etc., and animal products in which vegetable energy is stored up, are put to use by being worked upon and therefore preserved longer than when they are left to decay naturally. So that if one chooses one can translate into the physical world the old economic fact that all industrial producers have to live from the products of agriculture, cattle raising, hunting, and fishing—but there is hardly much to be gained from doing so [...]. (Engels 1968b)

Indeed, this 'old economic fact' warrants repeated examination in all countries that allows such accumulation of energy through the bio-physical route and more so, in the light of growing food prices across the world and the secular decline of per capita food and nutrient consumption in India, especially among the farming households. It may be noted that it is the cultivators who are responsible as economic agents for exchanges between human society and its environment, the part of the nature that serve as the source of materials, energy and also as a sink for the waste. Even if we leave aside the depletion and/or degradation of natural resource base, groundwater contamination from leaching and competitive withdrawal, pesticide residues in food, vegetables, and breast-milk, and adverse health impacts due to harmful exposure to chemicals, there are enough purely 'economic' reasons for birth of the term 'agrarian crisis'.

Sen and Bhatia (2004: 42) had warned that 'economic state of the average farmer, who is generally a small or marginal cultivator in most parts of the country' was
far from 'reasonable'. A series of committees and commissions were set up, reports were commissioned, action plans were announced, and occasional aid packages for the distress areas by the State and Central governments were advanced. Together, even intrinsically, these efforts can indicate the nature, extent, and seriousness of such a crisis.

The evidence was ample enough to prove beyond the reasonable doubt that (un)sustainability had been playing a contributory role somewhere. The usual suspects include agro-ecological aspects of crop production, and economic aspects of farming. Temporary relief in the form of debt waivers, could only postpone the crisis, at the most. While it may be difficult to establish the exact chain of causality for this phenomenon, nevertheless it is certain that walking along a few less travelled paths has become necessary to get closer to the truth.

The New Oxford Dictionary of English defines sustainable as 'able to be maintained at a certain rate or level'. Merriam-Webster defines 'sustainable' as (1) capable of being sustained and (2) of, relating to, or being a method of harvesting or using a resource so that the resource is not depleted or permanently damaged. Other dictionaries provide multiple meanings of the term sustain as 'keep going', 'maintain', 'support' or 'endure'. Likewise, sustainability means 'the ability to sustain something'. Sustainability is being applied to many situations and contexts over multiple scales of time and space, from total carrying capacity of the planet earth to a very local one like that of a farm. Due to its multiple applications and meanings in different context, sustainability is often perceived as nothing more than a feel-good buzzword with little substance.

Schaller (1993: 91) argued that popularity of the term 'sustainable agriculture' arises from its general appeal 'not only to people interested in an environmentally beneficial and healthful farming but also to those concerned with its economic and social dimensions'. At the same time, as a concept, this phrase pointed towards 'not only a destination for agriculture but particular farming practices

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that could move agriculture toward that destination'. Such a definition is not only imprecise, but it also helps in understanding the ambiguity and controversy accompanying similar terms that capture some of the dimensions of sustainability, as commonly understood, namely, 'organic', 'biological', 'ecological', 'reduced-input', 'low-input', 'regenerative', or 'alternative agriculture'.

[...] As a destination, sustainability is like truth and justice—concepts not readily captured in concise definitions. Nor can sustainable farming practices be defined easily, simply because no one can ever know precisely and finally which farming practices may be the most sustainable in every location and circumstance. (Schaller 1993: 91–92)

A detailed critical engagement with the notions of sustainability, or sustainable development or sustainability of agriculture certainly is beyond the present scope, but it may be sufficient to state that in the debate human labour/labourer was not given its due importance. This is rather strange given the list of issues that this debate has addressed so far:116 Radicals on the one side of the debate, as usual, have been arguing for redesigning of agriculture while status quoists have been calling for a fine-tuning of the existing agricultural practices. Central to this debate are the issues of profitability of sustainable farming, howsoever defined within this supposedly agro-environmental framework and the adequacy of food production under such a system, apart from the matters of scale neutrality, supply of adequate non-chemical inputs, price of such products, or even the certification programmes. However, what Schaller (1993: 96) had identified, a number of challenges remained:

[...] As one observer has put it, when you consider the energy inputs and costs in the distribution as well as production of food, you must ask harder questions. [...] To what extent does sustainable farming increase the well-being of rural people and communities? Do rural communities and institutions enhance or impair the ability of farmers to adopt sustainable practices? Beyond that, what is the connection between agricultural and rural sustainability and the rest of society?

A typical contribution from the agro-ecological side includes biodiversity, resource efficiency, productivity and economics, resilience, etc. as well as ecologically based soil nutrient management and participatory plant breeding with focus on livestock, livelihoods and innovation (see, for example, Snapp and Pound 2008). On the other hand, those who focus on labour concentrate on labour intensity, livelihood, displacement due to HYV technology, market for off-

116 Crop rotations that can break pest cycles and restoration of soil nutrients, supply forage and harvest feed; raising livestock for supply of manure and power; biological, mechanical, and other non-chemical methods for controlling insects, weeds, and diseases; soil and water conservation techniques with better scientific knowledge, to include just a few.
farm employment, etc. (see, for example, Tripp 2006). There is hardly anyone connecting the labourer and the soil. Index of The Earthscan Reader in Sustainable Agriculture (Jules Pretty, 2005) does include a variety of terms but not labour or labourers. Red and Green perspectives are perhaps at loggerheads for being too close to each other along with myopic visions.

1.6.1. Sources of Data and Brief Description of Field of Study

As indicated above, this work evaluates farming practices in the State of West Bengal, using the method of energy analysis, following the functional approach, in a comparative static framework. Temporally different datasets of Studies in the Economics of Farm Management (FMS) of 1956–57 and Comprehensive Scheme for Studying Cost of Cultivation/production of Principal Crops (CCS) 2004–05 were used. 1956–67 was the third year of the triennial 1954–57 that FMS had covered in the State of West Bengal, which had resulted in better quality of data, 'in the light of the experience of the first and second years' investigations' (1959: preface). On the other hand, 2004–05 was a normal year, as the yield data revealed. This dataset belongs to a series which has not been made public. Since 1986–87, it had been released only for research purposes, under certain conditions. 2004–05 was the latest normal year, and it was the same year in which Nutritional Intake in India: 2004–2005 (NSS 61st Round, July 2004–June 2005) had also taken place.

Practices in 1956–57 have been considered as 'organic', which by definition is true, and corroborated by the FMS reports through the absence of any direct chemical inputs. On the other hand, 2004–05 provides a variety of practices,
Introduction

from modern chemical based to those using only farmyard manure, without chemical pesticides and carried out under rainfed conditions.

Like its predecessor FMS, CCS collects data on all aspects of farming, including inventory of land, buildings, wells and tanks, livestock, machines, record of daily operations, wages, crop production, all kinds of human labour, bullock labour, machine labour, changes in inventory, land improvement work, animal and machine expenses, etc. on the basis of parcel, plot and seasons. This dataset had been argued to be suitable for 'Farm Energy sources, availability, use and economics' (CSO 2008: 42).

1.6.1.1. Cost of Cultivation Survey dataset for West Bengal 2004–05
Directorate of Economics & Statistics, Government of India has been presently collecting round the year information from 8000 operating holdings across the country, through state research institutions, under CCS.121 In West Bengal, presently 600 households are covered under this scheme, 10 each for 60 tehsils.122 Like FMS, it follows three stage stratified random sampling, with tehsil as the first stage sampling unit, a cluster of villages as the next stage and an operational holding in the cluster as the final and ultimate sampling unit. For the purpose of providing representation to all the areas in the states, samples were selected from all the agro-climatic zones, as defined by ICAR.123 The state falls under six agro-climatic zones, offering diversity, apart from various types of soil, variety of farm sizes, and irrigation practices. Data are collected from the same households for every three years. For the 'crop complex' during 2002–05 cycle, selected tehsils were distributed against five agro-climatic zones as the following:

121 After beginning in 1970–71, initially it had continued along with 'Studies in the Economics of Farm Management in India' (FMS). Latter was discontinued after 1972–3.
122 A.k.a., taluk and mandal or sub-districts, which is usually is an administrative unit, comprising several blocks.
123 In India, three agro-climatic/agro-ecological parallel classifications exist, prepared by three different Central government bodies: (1) Agro Climatic Regional Planning Unit, Planning Commission, New Delhi, (2) Indian Council of Agricultural Research (ICAR), New Delhi under the auspices of National Agricultural Research Project (NARP) with soft loans from International Development Agency, World Bank and (3) National Bureau of Soil Survey & Land Use Planning (NBBS&LUP), Nagpur of ICAR. These efforts had continued parallelly for some years. In table A.1.7.1, all the classifications have been approximately tallied against selected tehsils. While table A.1.7.2 provides the comparative basis, table(s) A.1.7.3–A.1.7.5, capture basic descriptions against specific regions/zones under each classification.

9 (II-terai), 14 (III-old alluvial), 17 (IV-new alluvial), 10 (V-red and laterite) and 10 (VI-coastal saline), leaving zone I (hill) unrepresented. Table A.1.7.6 contains the lists of villages under each of the blocks classified as a separate tehsil, along with the agro-climatic zone (ICAR-NARP) that the concerned agencies followed.

As green revolution packages had made a relatively late entry in the State, two kinds of seeds, local and improved, had been used. Fertile soil, with adequate water from rainfall or aquifer, and ample sunshine enabled triple cropping in many parts of the State. For example, it was common to find aman paddy, the kharif crop, boro paddy, the rabi crop and aus paddy, the summer crop. The distribution of plots against tehsil, crops, and seasons may be noted from table 1.7.1.

Farmer level field data, collected through investigators and supervisors in a specified schedule, was compiled at the State institution according to a specified format before processing it for the Central Analytical Unit at DES, for analysis and subsequent generation of the cost estimates to be used by Commission of Costs and Prices (CACP). While there are justifiable reasons to question the validity of data, in the absence of a better source, we can rely on this to get an idea of the intricately woven picture of the farming operations in the country (Sen and Bhatia 2004: 328).

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124 Within a single agro-climatic unit, however, significant differences in climatic factors may result in difference in vegetation and soils, and consequently in a variety of agro-ecosystems: in such cases, an agro-ecological region is carved out of an agro-climatic zone. Definitionally speaking, 'an agro-climatic zone is a land unit in terms of major climate, and growing period which is climatically suitable for a certain range of crops and cultivators. An ecological region is characterised by distinct ecological responses to macro-climate as expressed in vegetation and reflected in soils, fauna and aquatic systems' (Sehgal et al. 1992). Clearly, a single agro-ecological zone may lie over two adjoining states, districts or blocks notwithstanding the administrative boundaries. This poses a significant hurdle for the success of planning programmes that invariably assumes homogeneity across a unit.

125 Of the 60 tehsils, two blocks had more than one tehsil: Moynaguri had tehsil no.s 7 and 9, while Haripal had 25, 27, and 28.

126 It may be noted that a suffix 'A' with the table number denotes its location in the appendix; this nomenclature has been followed throughout the text.

### Introduction

Table 1.7.1: Distribution of plots across Tehsil, Crop and Season

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<th>Season 2 Total</th>
<th>Season 3 Total</th>
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Source: CCS WB 2004-05, RT 230
Notes: Analysis in this work excluded tehsil no 29, and perennial fruit crops in all tehsils altogether. Details of distribution of vegetables into individual crops is captured in table A.3.2.6. Mustard includes rapeseed as well.
Introduction

The choice of West Bengal is because of its significantly long history of food crop production. Further, the average farm sizes are smaller in comparison to most parts of the country, a part of the farm is usually kept for cultivation of food crops for self-consumption. Indeed, it is important to evaluate the efficacy of the land to the tiller, in terms of its ability to sustain the crop production. Finally, this State is one of the top producers of paddy, the cereal consumed by the majority of people in the state. It is also a well accepted physiological fact that this cereal contributes the most in the 'energy income' of the people.